Copyright 1928, by the AMERICAN SOCIETY OF NAVAL ENGINEERS.

JOURNAL
OF THE
AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. XL. AUGUST 1928. No. 3

The Society as a body is not responsible for statements made by individual members

COUNCIL OF THE SOCIETY
(Under whose supervision this number is published).

Rear Admiral JOHN HALLIGAN, U.S.N. — Rear Admiral C. W. DYSON, U.S.N.
Captain E. L. BENNETT, U.S.N. — Captain O. L. COX, U. S. N.
Captain R. B. ADAMS, U.S.C.G. — Lieut.-Comdr. E. L. COCHRANE, (C.C.) U.S.N.
Mr. J. F. METTEN — Mr. H. M. SOUTHGATE
Commander H. B. HIRD, U.S.N.

RIVER GUNBOATS FOR YANGTZE SERVICE
U. S. S. *GUAM* AND U. S. S. *TUTUILA*.

BY COMMANDER BRYSON BRUCE, U. S. NAVY, MEMBER.

For many years the United States has been represented on the rivers in Asiatic waters by a number of old gunboats, none of which were constructed for this particular duty, with the exception of two — the *Monocacy* and the *Palos*. These two vessels were assembled at the Navy Yard, Mare Island, California, taken apart, shipped to Shanghai, then put together and launched at a local dockyard. They were commissioned in 1914 and are still in service. The usual trials were not held when they were completed and consequently there has been no accurate information as to their performance. Reports on them during service brought out many features that were necessary and desirable for a gunboat on the Yangtze, most of which were not incorporated in these particular vessels — at least not satisfactorily.

About five years ago, the Navy Department decided that it would be necessary to build some new vessels for this service for replacements and the General Board made a study of the characteristics that a gunboat should have for service on the Yangtze.

The *Guam* and *Tutuila* were designed to navigate the Yangtze during all seasons of the year from Shanghai to Chungking, a distance of about 1500 miles. There is considerable difference of opinion among those with experience on the river as to the length, draft and speed, necessary for an all season vessel. The design is controlled entirely by that section of the river between Ichang and Chungking, which contains the famous gorges. During certain months, draft is a limiting characteristic and also length, at all times good speed is necessary and at times very high speed for the size of vessel. There are limits between which most of those of experience in the gorges place their estimates — the length given usually comes between 150 feet and 220, the draft from 3 feet to anything greater that the designer may wish, and the speed from 14 knots to all that can be obtained. In 1925, the General Board of the Navy decided on a vessel of not over 180 feet, not over 4 feet 6 inches draft and not less than 15 knots. Such a vessel was designed by the technical Bureaus of the Navy Department. With the limitations given above it was found necessary, in order to provide all the characteristics desired, to adopt Diesel engines, submarine type, for propulsion, as being the only satisfactory drive that could be installed in a vessel of this light draft to give the speed required.

Congress having authorized the construction of six river gunboats and appropriated funds therefor, the Navy Department in the summer of 1925 submitted plans and specifications to ship builders in Asiatic waters, requesting bids for construction of six vessels with Diesel engines and with characteristics, among others, as given above. At the same time alternative bids were requested for vessels of the bidders design.

On March 1, 1926, contracts were signed with the Kiangnan Dock & Engineering Works of Shanghai, China, for the construction of six gunboats of their design and of three different classes. Two of these vessels, the smallest class, will be described, and results of their trials given.

The Kiangnan Dock & Engineering Works is situated on the Shanghai side of the Whangpoo river a couple of miles above the old Chinese city. It is a Department of the Chinese Government under the control of the Ministry of the Navy. The dockyard was founded about sixty years ago for repairing ships of the Chinese Navy and about twenty years ago it was opened to commercial work also and has been developed to its present state, since that time, by the Chinese with the very able assistance of Mr. R. B. Mauchan, who was manager until recently. Ship and engine building and general repair work are carried on, not only for the Chinese Navy, but a very considerable amount of commercial work is handled. Over 500 vessels of all classes have been constructed to date, the largest of which were four 14,750-ton steel steam vessels built for the U. S. Shipping Board during the World War.

The design of the *Guam* and *Tutuila* is a credit to Mr. R. B. Mauchan, recognized among shipping circles in China as the greatest authority on vessels for service on the Yangtze river. This alternative design, submitted by the Kiangnan Dock & Engineering Works, was accepted by the Navy Department on recommendation of the Commander in Chief of the U. S. Asiatic Fleet and of the Commander of the Yangtze Patrol Force. This class was to have a length of 150 feet, draft not over 5 feet 3 inches and a guaranteed speed over the measured mile of not less than 14.5 knots.

NAMES.

The two vessels under consideration were originally designated as *PG43* and *PG44*. The keel of *PG43* was laid October 16, 1926, the vessel was launched on May 28, 1927, and christened the *Guam* by Miss Louise Frances Bruce, in honor of the United States island by that name. The keel of *PG44* was laid October 16, 1926, the vessel was launched June 14, 1927, and christened the *Tutuila,* by Miss Beverley Pollard, in honor of the American island of the Samoan group.

The *Guam* was commissioned as a U. S. gunboat on December 28, 1927, and the *Tutuila* on March 2, 1928.

GENERAL DATA.

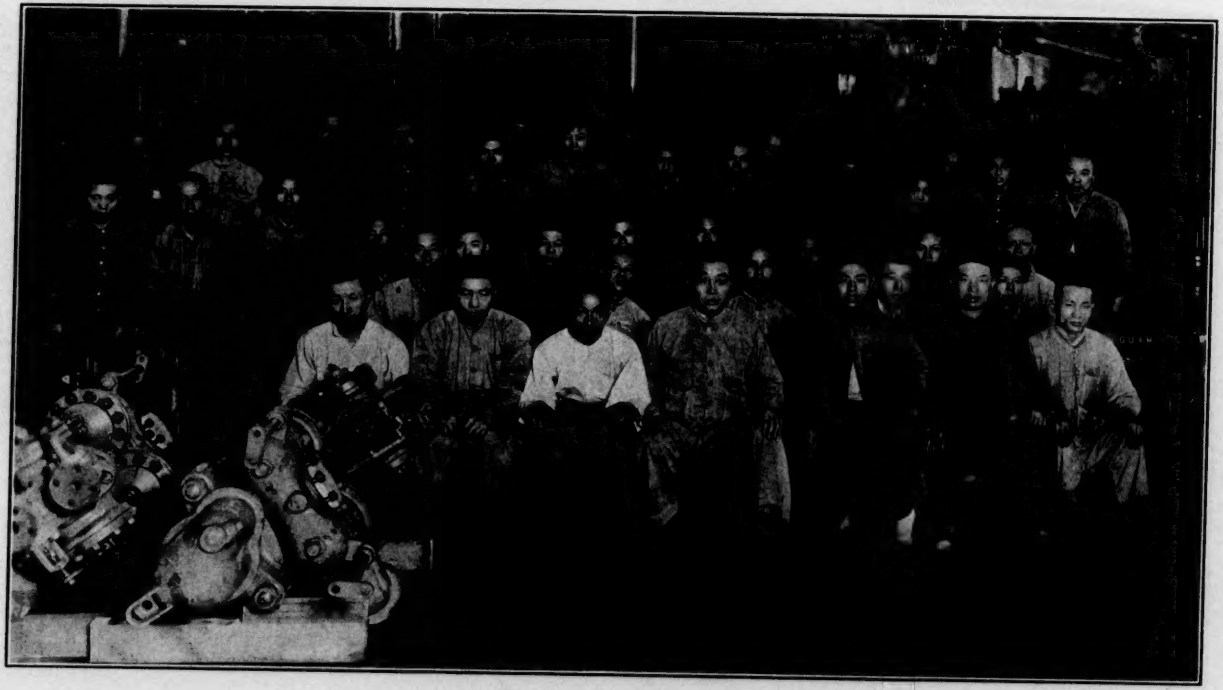
Length between perpendiculars, feet and inches	150 – 00
Length over all, feet and inches	159 – 03.25
Length on L.W.L., feet and inches	149 – 09
Beam, moulded, feet and inches	27 – 00
Beam on L.W.L., feet and inches	27 – 00.125
Beam, extreme, feet and inches	27 – 11
Draft, designed fresh water, feet and inches	5 – 03
Displacement on designed draft, tons	387
Displacement per inch on L.W.L., tons	7 – 55
Coefficient of fineness, block	.656
Coefficient of fineness, midship section	.991
Coefficient of fineness, L. W. L	.801
At designed draft, area immersed midship section, sq. ft	140.67
Area L.W.L. plane, square feet	3250
Area, wetted surface, square feet	4260
Gravity tank capacity, gallons	150
Fresh water, ships tanks, gallons	2040
Reserve feed tank, tons	7.12
Engine room feed tank, gallons	100
Fuel oil carried on designed draft, tons	26
Fuel oil bunker capacity, tons (95 per cent full)	77.48

GENERAL DESCRIPTION.

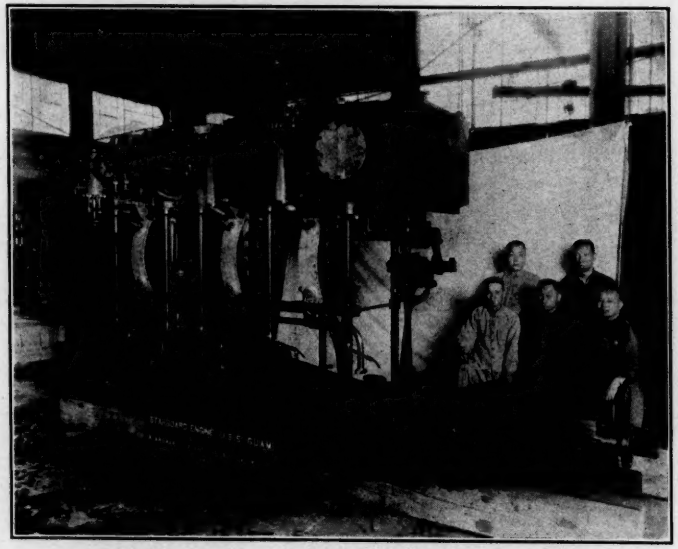
The general data of the hull of the *Guam* and *Tutuila* is as given above. They are twin screw open stern boats with three rudders and a spoon bow. Construction throughout is of the lightest weight consistent with necessary strength for river service. All structural steel work, plates, iron and steel fittings, etc., are galvanized by the hot process except bullet proof plates.

The main deck extends throughout the length of the vessel except for the greater part of the engine room space, the fireroom and forecastle. There is a forecastle deck about four feet above the main deck and a platform deck underneath the greater part of the forecastle deck and about four feet lower than the main deck level thus providing the space for the anchor and capstan engine. Beneath this compartment are the chain lockers and forward of it a peak tank.

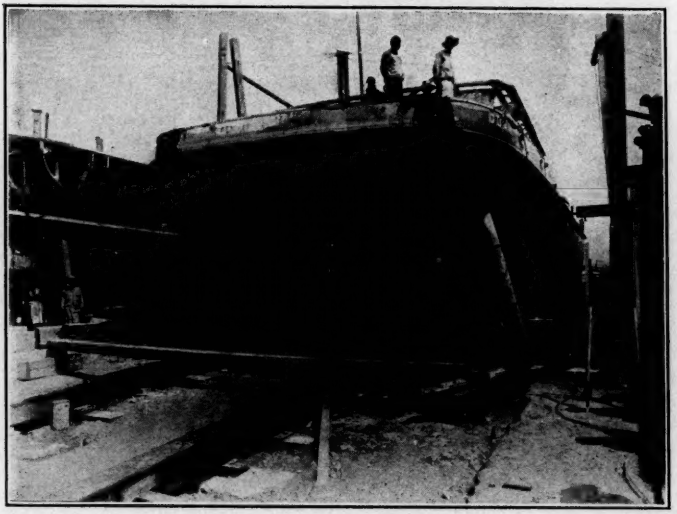
Aft of the anchor engine space in the hold from frames 11 to 20 are store rooms with the forward magazine located in the after



MACHINE SHOP CREW,
KIANGNAN DOCK AND ENGINE WORKS,
SHANGHAI 1927.



STARBOARD ENGINE, U. S. S. "GUAM," SHANGHAI 1927.
Seated—No. 1 Molder, No. 1 Coppersmith and No. 2 Patternmaker.
Standing—No. 1 Fitter and No. 1 Machinist.
No. 1 Molder, Tong Yu Liang. No. 1 Coppersmith, Li Yuan Fu.
No. 2 Patternmaker, Li En. No. 1 Fitter, Shü Wen Shang.
No. 1 Machinist, Shen Chung Ka.



U. S. S. "GUAM"—STERN VIEW JUST PRIOR TO LAUNCHING MAY 28, 1926.

part of the compartment on the centerline. Frames are spaced two feet apart. A trunk leads up to the forward gun.

From frames 20 to 28 are situated, on the starboard side, a compartment for mess attendants, and on the port side the ship's office, canteen and armory with the ship's fresh water tanks in this compartment, the larger of the two, on the centerline. Access to each compartment is by vertical ladder through a twenty-four inch opening.

The boiler room extends from frames 28 to 44 with fuel oil bunkers outboard, three to a side.

The engine room extends from frame 44 to 58.

Aft of the engine room there is a compartment which extends to frame 70. The shaft tunnels extend through this compartment. Between the tunnels in the forward part of the compartment is the after magazine separated from the engine room by a cofferdam. Entrance to the cofferdam is by scuttle in the main deck and the shaft tunnels may be entered from this cofferdam. On the starboard forward side is located the refrigerating plant and in the corresponding place on the port side are two small cold storage rooms. The remainder of the compartment is used as storeroom space being separated into rooms by steel meshed bulkheads. A hatch leads to the main deck and a second hatch to the upper deck for service of the after gun.

From frame 70 to 76 is the after peak which has been fixed up for native crew.

Above the main deck is the upper deck extending from frame 8 to 70. There is a passageway on both sides of the main deck about four feet wide and in places the upper deck extends over a part of these passageways.

There is a stateroom on each side forward between frames 10 and 15. The starboard one is single, the port double, but ordinarily occupied by one officer. The wardroom is directly aft of these staterooms occupying four frame spaces. Aft of the wardroom the next three frame spaces, are used for the wardroom toilet and shower on the starboard side and the wardroom pantry on the port side.

There is a passageway occupying two frames, 22 to 24, and then the galley has four frames which brings us to the forward fireroom bulkhead.

The fireroom and engineroom take all space on this deck from frame 28 to 54 including a passageway just forward of frame 54.

From frame 54 to 67½ is the crews quarters and aft of these quarters to frame 70 are the crews toilets and washrooms.

On the upper deck are several deck houses. The forward gun is located just forward of the bridge on this deck between frames 8 and 15. The bridge, which extends nearly across the vessel, is raised about four feet, and the space underneath is used for stowage.

Aft of the bridge is the captain's stateroom extending the width of the deck house and opening into a toilet and bath on the port side. On the opposite side is an officers' stateroom. The after part of this deck house contains the radio room which extends over the fireroom. The top of this deck house, except the part over the radio room, is clear of any encumbrance and makes a pleasant lounging place for officers under the awning.

Aft of the radio room there is the housing for uptakes of forward boiler with a space of two feet between the radio room and its forward bulkhead. There is a passageway of six feet, then the housing for uptakes of after boiler, then the engine room trunk and skylight.

The C. P. O. quarters are situated from frame 47 to 53.5, additional crews quarters from 53.5 to 59.5 and the sick bay from 59.5 to 64.5 and the remainder of this deck is occupied by the after gun.

There are two masts, two smoke pipes, two fireroom ventilators and two engineroom ventilators.

The main deck is bare steel where exposed to the weather but covered with linoleum in living space. The upper deck is a one-inch teak wood deck covered with heavy canvas where exposed to the weather. The bridge has linoleum.

COMPLEMENT.

Officers—Line	3
Medical	1
Total	4

Men—	C. P. O.	4
	Other ratings	44
	Total	48

CREW — BERTHING AND MESSING.

The C. P. O. quarters, aft on upper deck, have folding berths, two high, with lockers underneath the lower berth, to accommodate six. There is space for a standing mess table.

The crew is accommodated in the large crew space aft on the main deck and a small compartment on the upper deck. The large compartment has lockers and berths for thirty men and space for portable mess tables for entire crew. The small compartment takes care of eight men for berths and lockers. The berths are three high. All these living quarters have windows with shutters along both sides and are well ventilated. The large crew space on the main deck has one 1000 cubic foot bulkhead intake fan on each side. There is a scuttle butt in this compartment and several electric fans. There is a compartment for four servants in the hold starboard side forward and in fantail for ten native crew.

GALLEY.

There is but one galley, which is well located on the main deck, containing two oil burning ranges with ventilating trunk over the ranges, which extends above the awnings over radio room and officers quarters on the upper deck. The galley smoke pipe is inside the trunk and extends out above the awnings. Oil is ordinarily burned by use of steam but an air compressor is located in the galley for auxiliary use with accumulators in the fireroom. The galley is well equipped with the usual utensils plus three 10-gallon pressure cookers and a refrigerator.

FRESH WATER SYSTEM.

Fresh water is furnished by the evaporator to a two compartment ship's tank forward, which holds 2040 gallons. Water may be pumped to the gravity tank by a steam pump in the engine room or a hand pump located outside the galley in the athwartship passageway. Water is supplied by a piping system from gravity

tank to all staterooms, wardroom pantry, galley, officers and crews baths, sick bay, scuttle butt, ice making box and to hot water heater. Hot water from the heater is supplied to galley and all officers staterooms, wardroom pantry and bath. Hot water for sick bay and crews wash room is obtained by local steam heaters. This system is arranged so that only distilled water can be used for all purposes as any other water in China is contaminated and must be boiled before being used.

BOATS.

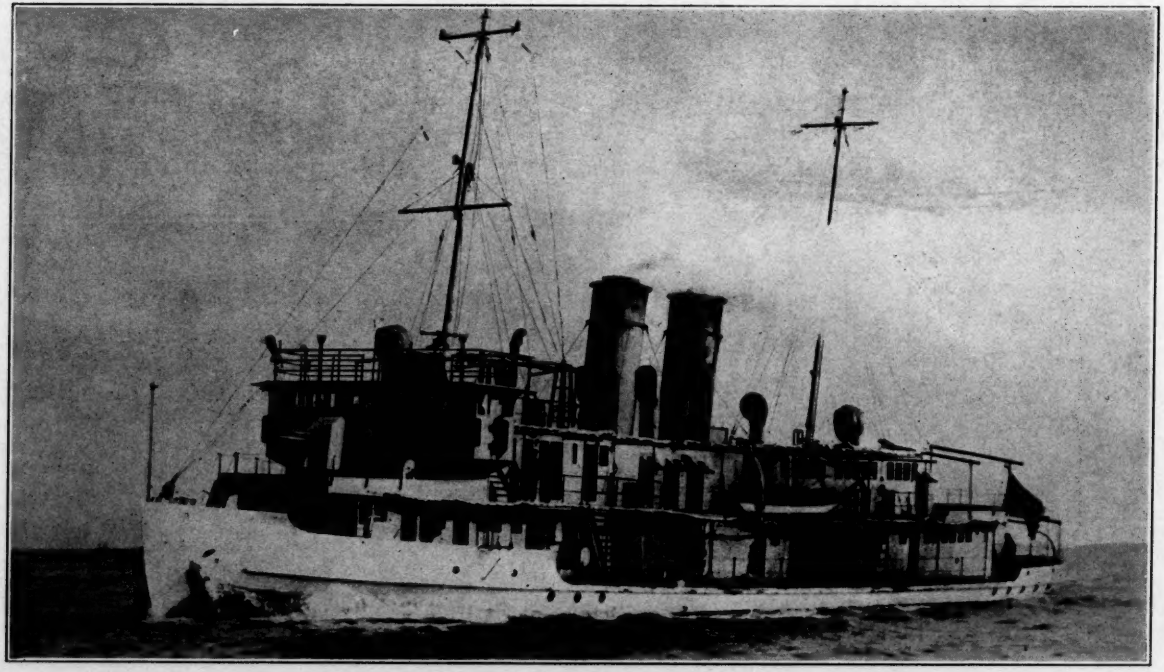
There is one 26-foot motor sampan which hoists amidship on the starboard side and stows on the upper deck. This boat has a cock pit forward which will accommodate ten men. It is powered with a high speed light weight engine, Model 50, manufactured by the Kermath Manufacturing Co., Detroit. On account of its light draft — about 13 inches — the propeller — nineteen inches — is placed in a tunnel. It is equipped with electric side and trouble lights, search light, electric horn and the usual boat equipment, engine accessories and spare parts. The hull is constructed with galvanized steel frames and teak wood throughout. There is a permanent wind and spray shield with doors for entrance at the forward end of the cock pit and the cock pit is covered with a canvas automobile type top.

There is one 22-foot pulling sampan which hoists on the port side and swings from the davits. It is of the usual type and constructed throughout of teak wood.

Boats may be hoisted by means of the capstans or by hand.

FIRE AND SANITARY SYSTEM.

The fire and sanitary system is a combined system. There are 1½-inch fire plugs on each side of the main deck. Water is furnished by this system for fire, sanitary use and magazine flooding. Water is furnished to this system by two steam general service pumps in engine room and one motor driven reciprocating pump in engine room for use in case there is no steam on the ship.



U. S. S. "GUAM"—THE FIRST OF OUR SIX NEW CHINA RIVER GUNBOATS.

ANCHOR GEAR.

On account of the necessity to haul over rapids on occassions it is very necessary that a vessel built to operate in the gorges shall have a substantial and reliable anchor engine and gear.

The engine is located below the forecastle deck between frames 6-9 in its own compartment. It is a two-cylinder single expansion vertical steam engine, 7½-inch bore and 6-inch stroke, designed for full boiler pressure and built by the Kiangnan Dock & Engineering Works. By means of bevel gears, worm and worm wheels, the engine drives two vertical shafts connected to the wildcats and capstans on the forecastle deck.

Control of the engine is at the engine, on the forecastle in proximity to the wildcats, or from the gun platform, a few feet above the forecastle from which station the operator has bullet proof protection. A clutch at the engine makes it possible to operate either wildcat and capstan singly or both at one time. It is also possible to operate by hand.

There are two stockless bower anchors of 1300 pounds each, Eells type, stowed in hawse pipes. One 500-pound Navy standard stockless stern anchor stowed on the main deck aft. The starboard bower anchor has 90 fathoms, and the port bower 75 fathoms of one-inch government standard cast steel chain. The chains after passing around wildcats lead forward and through vertical chain pipes to chain lockers located in the hold below the anchor engine compartment.

A socket is fitted aft on each side for davit to handle the stern anchor.

AFTER CAPSTAN.

A capstan is located aft on the main deck at frame 73 on the centerline. It has a vertical type head driven by a two-cylinder horizontal single expansion engine through worm and worm gear. The engine is designed for boiler pressure, the cylinders are 4½-inch bore and 4-inch stroke. It is controlled locally by a lever. It may be operated by hand.

STEERING GEAR.

There are a center and two wing rudders of a total area of 63.3 square feet. The three-rudder tillers are connected with tie rods.

The steam steering engine is located at the main deck level in the engine room on the centerline between frames 51 and 53. It is operated from the pilot house by means of a shaft and gears. It may also be operated locally. The engine is a two-cylinder, horizontal, single expansion engine designed to use full boiler pressure. Cylinders have 4½-inch bore and a 4-inch stroke. The drive is by worm and worm wheel. The engine, as well as the entire steering equipment, was built by the contractor.

The steering chain from the steering engine leads aft around a traveling double purchase block and then forward along the outboard edge of the main deck to the hand steering stand in the after part of the pilot house on the centerline. The double purchase block is connected with chains and rods to the tiller of the wing rudders. These chains and rods are heavily constructed and with necessary sheaves along the deck add considerable weight and are clumsy to install, but have the advantage of being very satisfactory otherwise.

The steam steering stand has a handwheel about 30 inches in diameter. The hand steering stand has two teak wheels about 60 inches in diameter. The hand gear may be put in commission by simply unscrewing a locking pin in the pilot house.

PILOT HOUSE.

The pilot house extends nearly across the vessel and has a door near each end opening to a short ladder which leads to upper deck passageway on each side. The doors are of bullet proof steel as well as the sides and top. There are windows across the front and sides with bullet proof shutters and screens.

There are the steam and hand steering wheels, binnacle, engine order telegraph, voice tubes, chart board, steam radiators and whistle and siren pulls located in the pilot house. The deck is covered with linoleum. The top of the pilot house has a railing with flag rack, 24-inch searchlight, signal searchlight, range finder,

pelorus on each side, and blinker light key on each side. All steel on side and top of pilot house exposed to the sun is insulated on the inside with cork.

SICK BAY.

The sick bay is located aft on the upper deck, has two berths, toilet, desk, drawers and racks for equipment, electric sterilizer and portable operating table.

AWNINGS.

There are single or double awnings provided for all exposed deck space and over all deck houses which are very necessary for comfort during the hot summer months. The sides of all living compartments that are exposed to direct rays of the sun are insulated on the inside with cork.

ORDNANCE.

There are two 3-inch, 23 caliber, anti-aircraft guns, with bullet proof shields, one located aft and one forward on the centerline. The forward gun can fire from about two points aft of each beam through the arc forward, and the after gun from about three points forward of each beam through the arc aft. There are also eight mounted machine guns, four on each side. They are equipped with bullet proof shields which train with the guns. There is also the usual equipment of small arms and a one meter range finder.

MACHINERY INSTALLATION — CHOICE OF TYPE.

The design of the machinery installation for a Yangtze river gunboat to operate in the gorges is limited by several conditions. In the first place the vessel is small, of light draft and of a very light construction, and the power required to give the speed necessary in the gorges is high considering the size of the vessel.

The draft limits, the propeller size, necessitating high speed of propellers, at least for certain types of main engines, and light weight is a prime requisite in any type that may be adopted. The question of the possible engine foundations and rigidity of hull structure must be taken into account, together with the further fact

that the propellers operate near the surface of the water and are subject to pulsations of power due to this and on account of the turbulent water in the rapids of the gorges.

There are several types of main propelling machinery that suggest a possible solution of the problem, each having its advantages, but some having at least one serious defect to eliminate its consideration.

The type most familiar on the river and the easiest to operate and care for with local facilities is the reciprocating steam engine with oil burning water tube boilers such as the *Guam* and *Tutuila* have. The main objection is the necessary light weight and high speed which are forced on the designer.

Direct connected Diesel drive with a flexible coupling between engine and thrust bearing could undoubtedly be made satisfactory and would be the lightest in weight and of course considerably more so if the fuel necessary for a given cruising radius is taken into account. The principal objection is the necessity for high class personnel to operate and make necessary repairs. The keeping on hand of a liberal amount of spare parts would assist in overcoming these objections. The objections to this type of drive do not outweigh its very great advantages, and it deserves serious consideration in any design. The first cost would greatly exceed the reciprocating engine drive.

Turbo electric drive has many good points but it has one very serious objection in a vessel of this power and displacement which precludes its serious consideration, and that is weight.

Any form of geared drive would probably give serious operating difficulties due to the vibrating pulsations in power being transmitted by propellers on account of their location near the surface and the turbulent water of the gorges.

A vessel of 180-foot length and 4 feet 6 inches draft with Diesel drive was designed for this service by the Navy Department to give a speed of 15 knots. More recent information as to river conditions influenced the General Board to decide that a draft of 5 feet 3 inches, or at most not over 6 feet, would be satisfactory. This made it possible to adopt reciprocating engines, which were first considered for the Department's design, and with all things taken into account it was decided by the Department to accept the

design submitted by the Kiangnan Dock & Engineering Works. From the results of the trials of the *Guam* and *Tutuila* it is evident that the Navy Department Diesel design would have come up to requirements.

CONTRACT REQUIREMENTS AND RESULTS.

The contracts required a speed of not less than 14.5 knots over a measured mile and a fuel capacity to give a steaming radius of 1000 miles at 10 knots. The draft with two-thirds supply of fuel, lubricating oil, water and consumable stores was not to be greater than 5 feet 3 inches. It should therefore be noted that a steaming radius of 667 miles on the draft of 5 feet 3 inches would fulfill contract requirements, providing bunker fuel capacity was sufficient for 1000 miles. There was a severe penalty for failure to make the speed, and also a penalty for overdraft or failure to meet the cruising radius requirement. The boiler installation was to produce the steam necessary for 14.5 knots for main engines and other uses while burning not over .5 pound of fuel, 19,000 B. T. U.'s per pound, per square foot of heating surface. There was no penalty for failure to meet this requirement.

The design was for 14.5 knots at 320 R. P. M. and 1950 I. H. P. The trial results were 14.5 knots at 323 R. P. M. and 1410 I. H. P. for the *Guam* and 322 R. P. M. and 1385 I. H. P. for the *Tutuila.* The steaming radius required was 1000 miles at 10 knots. The bunkers of each vessel hold 77.48 tons of fuel oil at standard gravity and temperature. In the case of the *Guam* the trial results indicate that it requires 39.42 tons per 1000 miles leaving a possible reserve supply of 38.06 tons, and in the case of the *Tutuila* the corresponding figures are 34.75 tons and 42.73 tons. The maximum speed and corresponding I. H. P. were: *Guam,* 15.62 knots and 2048 I. H. P.; *Tutuila,* 15.61 knots and 1956 I. H. P.

It will be seen from the above that the speed was exceeded by over 1.1 knots, the required cruising radius was equalled with 38.06 tons of reserve fuel in the case of the *Guam* and 42.73 tons in the case of the *Tutuila.* The difference was due undoubtedly to the experience in operation that the Chinese crew had obtained. Actually there is not considered to be any real difference in the

vessels. It should be noted that the vessels have a radius of about 2000 miles providing it is permissible to accept the increased draft, which can be done in the lower river. The only requirement not met or exceeded was the pounds of oil per square foot of heating surface for which there was no penalty. However, this requirement might possibly be met with experienced operation but is of no consequence as the boiler installation is capable of furnishing an excess of steam under any and all conditions without undue forcing.

ARRANGEMENT OF MACHINERY.

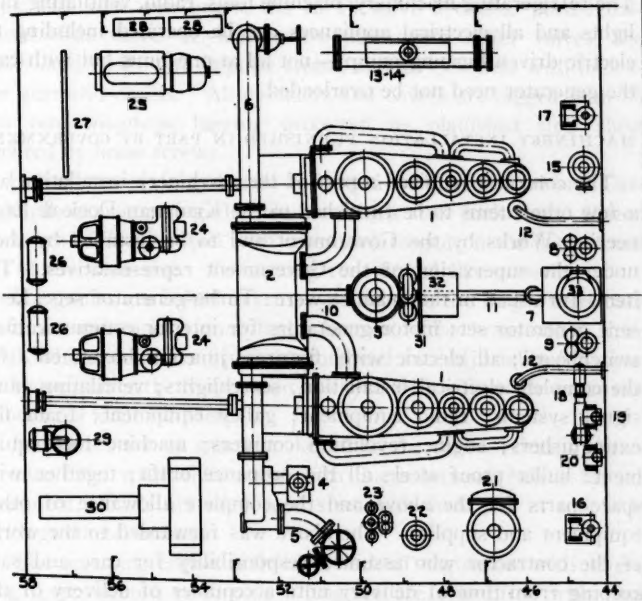
The accompaning sketches show the arrangement of the engine room and fireroom and, although not exactly to scale, give a very good idea of the space for operation and overhaul. The skill, and particularly the patience of the Chinese workmen, shows up in the arrangement of many minor details which taken in the aggregate affect materially the workman like appearance and the ease of operation and upkeep.

OPERATION UNDERWAY.

Underway there is no special conditions except there is only one main condenser, one main air and one main circulating pump. It is possible to put the general service pumps on the condenser and to drain it — with the atmospheric valve open — to the reserve feed tank. Generally underway both boilers will be in use, or at least in the gorges, as a precautionary measure.

OPERATION IN PORT.

A feature in port operation, which means a considerable saving in fuel, is the installation of a Ray Rotary oil burner, electric driven, on each boiler. With this burner, which is supplied with oil direct by a small electric driven pump set, it is possible to operate with an open fireroom and unnecessary to use the forced draft blowers, steam fuel oil service pumps and fuel oil heaters. In weather where steam heat is unnecessary and with a supply of fresh water, fires may be died out in both boilers, the 10 K. W. kerosene generating set operated and the vessel can accomplish all



1 MAIN ENGINE
2 MAIN CONDENSER
3 MAIN AIR PUMP
4 MAIN CIRC. PUMP
5 MAIN INJECTION
6 OUTBOARD DELIVERY
7 HOTWELL
8 MAIN FEED PUMP
9 AUX. FEED PUMP
10 MAIN AIR PUMP SUCTION
11 MAIN AIR PUMP DISCHARGE
12 MAIN STEAM
13 AUX. CONDENSER
14 AUX. AIR & CIRC. PUMP
15 GREASE EXTRACTOR
16 GEN. SERVICE PUMP-STBD.
17 GEN. SERVICE PUMP-PORT
18 GEN. SERVICE PUMP-ELECTRIC
19 FRESH WATER PUMP
20 SANITARY PUMP
21 EVAPORATOR
22 DISTILLER
23 EVAP. FEED & DIST. CIRC. PUMP
24 25 K.W. TURBO-GENERATOR
25 10 K.W. OIL ENG. GENERATOR
26 I.C. MOTOR GENERATOR
27 MAIN SWITCHBOARD
28 SEARCHLIGHT RHEOSTAT
29 SENSITIVE DRILL
30 COMBINATION LATHE
31 GAUGE BOARD
32 LOG DESK
33 FEED HEATER

FIG. 1

tasks usually requiring power except to pump up the gravity tank. The refrigerating machinery, machine tools, radio, ventilating fans, lights and all electrical appliances can be operated including the electric driven flushing pump — not all at one time, but with care, the generator need not be overloaded.

MACHINERY INSTALLATION FURNISHED IN PART BY GOVERNMENT.

The contracts required a part of the machinery installation and a few other items to be furnished to the Kiangnan Dock & Engineering Works by the Government and to be installed by them under the supervision of the Government representatives. The items furnished in this manner were: Turbo-generator sets; kerosene generator set; motor generators for interior communication; switchboard; all electric wire, fixtures, junction boxes, etc., for the complete electrical installation; searchlights; ventilating fans; signal systems; radio equipment; galley equipment; foam fire extinguishers; engine revolution counters; machine tool equipment; bullet proof steel; all the ordnance outfit; together with spare parts for the above and the complete allowance of other equipment and supplies. The above was forwarded to the works of the contractor who assumed responsibility for care and safe keeping from time of delivery until acceptance of delivery of the completed vessel.

MAIN ENGINES.

There are two main engines, triple expansion, inverted vertical, three cylinders arranged in order and with diameters as follows: H. P., 12 inches; M. P., 18 inches; L. P., 29 inches. The stroke is 16 inches and designed R. P. M. 320.

The engines are built on a bedplate consisting of two steel channel bars carrying cast steel transverse girders for support of main bearings and the forged steel engine columns, machined all over. The thrust block is carried by these steel channel bars also, and the whole is securely bolted to the engine foundation.

Cylinders are cast separately of close grained cast iron and are firmly secured to each other with faced joints and fitted bolts. The H. P. cylinder has a cast iron liner. Each valve chest is cast

integral with its cylinder. The H. P. and M. P. valves are piston type with cast iron liners, the L. P. valve a double ported balanced slide valve. Cylinders are fitted with relief valves, the M. P. and L. P. with impulse steam, and all cylinders with indicator gear and drains. All cylinders and covers are lagged with 85 per cent magnesia lagging protected by planished steel sheet secured by brass screws.

Pistons are of forged steel and fitted with Lockwood and Carlisle patent piston rings held in place by a steel junk ring. Piston rods are of forged steel with crosshead forged on the bottom and all of the same size. Connecting rods are of like material.

The guides are bolted to cross bars fitted to the forged steel back columns and to lugs on cylinder bottom. The brass shoes, lined with white metal, are fitted to crosshead and adjustable for wear.

Valve gear is the Stephenson link type with adjustable expansion blocks for each cylinder.

Eccentrics are of cast iron keyed to the shaft. Straps are of bronze lined with white metal with liners between halves for adjustment. Rods are of forged steel with fork end at top fitted with gunmetal brasses.

The reversing engine is fitted at back of engine but with reversing lever located at throttle. Engines are also fitted with hand reversing gear and jacking gear.

The crank shaft is a built up forged steel shaft with three cranks 120 degrees apart.

The thrust block is a steel casting fitted between channel bars of engine bed plate. It has a bearing at each end and five collars on the shaft with five cast steel white metal lined horse shoes, each arranged to be adjustable and removable, with water cooling.

Main bearings are bronze lined with white metal held in place by polished steel caps, steel bolts, nuts and locking pins. They are fitted with brass oil boxes with hinged covers.

Lubrication is by hand. All working parts are fitted with brass oil boxes and tubes as necessary.

Main bearings and guides are fitted with water service. The bearings by means of brass telescope tubes. Water supply is taken from the main circulating pump or general service pumps.

The finish of the engines is excellent which may be seen from the photographs reproduced. In addition to good appearance the trial results were highly satisfactory. It should be remembered that they are of light weight and high R. P. M. — 360 possible — and need to be treated as a light duty rather than a heavy duty engine. The parts are all readily accessible with good headroom for working over cylinders with lifting gear and chain hoists always at hand.

The engines were entirely the product of the Kiangnan Dock & Engineering Works with the exception of the patent piston rings, and the rough steel castings.

MAIN CONDENSER.

There is one main condenser of Uniflux type situated as shown on the sketch. It has 1346 square feet of cooling surface, 1055 tubes ¾ inch in diameter and 6 feet 8.25 inches long. Tubes are packed at both ends in rolled brass tube sheets. The shell is of steel and the heads of cast iron fitted with inspection plates. The delivery pipe from circulating pump is on the starboard side and is 11 inches in diameter, the overboard discharge of like diameter is on the port side. Both main engines, the turbo-generators, circulating pump, air pump and steering engine exhaust directly to the main condenser. The main air pump may also be cut into the auxiliary exhaust. The auxiliary exhaust may be cut into main condenser if desired.

MAIN AIR PUMP.

There is one main air pump between the main engines forward of the main condenser. It takes suction from the condenser and discharges to the hot well between the main feed pumps near the forward engine room bulkhead. It is vertical simplex type, $12 \times 24 \times 15$, manufactured by G. & J. Weir. The suction is 6 inches and discharge 5 inches in diameter. This pump exhausts either to main condenser or auxiliary exhaust line.

MAIN CIRCULATING PUMP.

It is located on the starboard side near the main injection, is of centrifugal type and driven by a single cylinder engine of 5¼-inch

bore and 4-inch stroke. It takes suction from sea or bilge and discharges to main condenser and overboard. Water is taken from the discharge of this pump for engine water service. Manufactured by the Kiangnan Dock & Engineering Works.

MAIN FEED PUMPS.

There are two Weir main feed pumps located in the forward part of the engine room. They are of vertical simplex type, 10½ × 7½ × 12, with 3½-inch suction from feed tank, reserve feed tank and overboard, and 3-inch discharge to boilers via the grease extractor and feed heater, or these may be by-passed.

AUXILIARY CONDENSER.

A Worthington surface type auxiliary condenser is installed. It has 142 square feet cooling surface, may be supplied with cooling water by its own pump or the general service pumps. It takes the auxiliary exhaust and turbo-generators on vacuum by direct line. It is equipped with the usual air and circulating pump, 5½ × 8 × 8 × 7.

OTHER PUMPS IN ENGINE ROOM.

Located on the starboard side of the engine room on the forward bulkhead are two Worthington vertical simplex pumps, 3½ × 4 × 4. One of these pumps is the fresh water pump and can be used only for potable water, the other is connected to the fire and flushing system for sanitary purposes.

GENERAL SERVICE PUMPS.

There is a Worthington vertical simplex general service pump on each side of the engine room forward. They are of 6½ × 7 × 8 size and take suction from sea, engine room bilge and fireroom bilge. They discharge to fire main, flushing system, auxiliary condenser, filterer, engine water service and main condenser. An electric driven reciprocating Gould pump is installed for water service, principally flushing, when there is no steam on the ship. The pump has a 3-inch bore and 2¾-inch stroke and is driven by motor and silent chain.

DISTILLING PLANT.

The distilling plant is of Weir design and manufacture, of high pressure type and has a capacity of 200 gallons per hour. It is located on the starboard side of the engine room and consists of one Weir evaporator, one distiller, a combined evaporator feed and distiller circulating pump, an evaporator feed tank and an evaporator feed filter tank located on the upper deck in the passageway between the uptakes. A Worthington fresh water pump takes suction from the distiller, also the ship's tanks, and discharges to reserve feed tank, ships tank and gravity tank. It is located on the forward engine room bulkhead and is a vertical simplex $3\frac{1}{2} \times 4 \times 4$ size. In operating the evaporating plant water from overboard is taken from the firemain to the filterer on deck, where the silt and dirt is removed, keeping it from collecting in the evaportor. Water, after being filtered, flows to the evaporator feed tank from which it is taken by the evaporator feed pump. On account of the possibility of water in China being contaminated it is necessary to use a high pressure evaporator and to observe care to keep all contaminated water out of the fresh water system.

TANKS.

There are six fuel oil tanks, three on each side outboard of the boilers having a total capacity of 77.48 tons, when 95 per cent full. Two lubricating oil tanks on the starboard side of the upper deck and piped to upper gratings in engine room, one for wick feed oil holding 135 gallons, and one for forced feed oil holding 67 gallons. In a similar place on the port side a kerosene tank is installed having a capacity of 210 gallons. It is piped to the engine room to a small service tank for the kerosene engine driven generator. There is a lubricating oil tank in the vicinity of the ice machine which will care for 80 gallons of ice machine oil. The ship's gravity tank has a capacity of 150 gallons, the ship's storage tank 2040 gallons, the reserve feed 7 tons and the feed and filter tank 100 gallons.

SHAFTING.

There are the following separate pieces of shafting per engine, one crank shaft, thrust shaft, two sections of line shafting and propeller shaft. All shafting is solid forged steel, and is interchangeable between sides of the ship and between vessels. A spare propeller shaft was furnished for each vessel.

PROPELLERS.

The propellers are out turning, four blades, solid, bronze, cast and finished by the contractor. The pitch is 6 feet 9 inches and diameter 5 feet 3 inches. A spare set of propellers was furnished for each vessel.

LUBRICATION.

Lubrication of main engines and other machinery is by hand or wick feed except forced feed is employed for forced draft blowers and turbo-generator sets. The stern tube and strut bearings are fitted with white metal bearings enclosed by means of the stern tube in an oil tight system. Oil is forced into the system at the forward end of the stern tube bearing through the pipe which forms a casing for the propeller shaft, through the strut bearing and back through a return pipe to a small oil tank near the deck in the after compartment of the vessel.

REFRIGERATING MACHINERY.

There is a 1-ton CO_2 direct expansion system refrigerating plant located on the starboard side in the compartment aft of the engine room. The refrigerating piping is lead through the cofferdam to the refrigerating rooms on the port side of this compartment. There are two of these rooms, one of 157 cubic feet and one of 141 cubic feet. An ice making tank is located near the machine of standard four cake size and the scuttle butt is located in the crews' compartment overhead. The refrigerating machinery is by the York Manufacturing Company, is motor driven, five horsepower, and can be operated by the kerosene generator when there is no steam on the ship.

REPAIR EQUIPMENT.

An unusual feature of a vessel of this type is the repair facilities installed. There is a combined lathe, milling machine, and drill installed in the starboard after corner of the engine room. It is driven by belt and motor and is capable of considerable variety and amount of work in the hands of a competent operator. Lockers are arranged handily for the various accessories. This combination machine is manufactured by the Dalton Manufacturing Co. There is a sensitive drill, work bench and vise located in this corner of the engine room near the lathe. The drill is motor driven. There is a pedestal type two-wheel grinder, electric driven, located on the upper deck. A portable blacksmith's forge and tools are furnished.

MISCELLANEOUS.

There is a steam heating system which leads from the engine room forward and aft to the various compartments to be heated. A Leslie reducing valve is located for this system in the engine room. All radiators are of brass, coil type, except in quarters, pipe surface of the steam lead is used for radiation where convenient. The system discharges to a trap in fireroom.

There is a hot water tank heater located in the fireroom which takes steam from the heating system to furnish hot water to quarters and baths forward. In the sick bay and crews' baths which are located aft, hot water is obtained with local individual steam hot water heaters.

There is a whistle and siren located on the forward stack with pulls on the bridge. They are of Kiangnan Dock & Engineering Works manufacture.

There is a Cummings revolution counter on the gauge board between the main engines fitted with a tell tale.

The feed heater, located on the forward engine room bulkhead, is of Weir design and manufacture and has 90 square feet heating surface. It may be by-passed.

There is one cartridge type grease extractor located on the forward engine room bulkhead and fitted with by-pass.

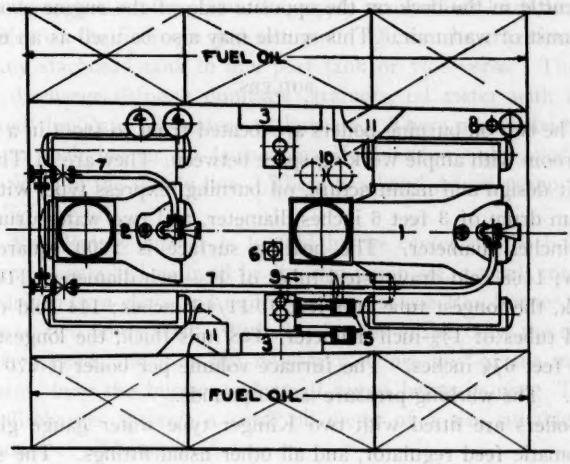

FUEL OIL
FUEL OIL
1 FORD BOILER
2 AFTER BOILER
3 BLOWERS
4 FUEL OIL HEATERS
5 FUEL OIL PUMPS
6 HAND FUEL OIL PUMP
7 MAIN STEAM
8 HOT WATER HEATER
9 GALLEY AIR TANKS
10 FOAM FIRE EXTINGUISHER
11 AIR LOCKS

FIG. 2

There is a 5000 cubic feet ventilation fan in the port after corner of the engine room near the switchboard for intake of air and a scuttle in the deck on the opposite side of the engine room for exhaust of warm air. This scuttle may also be used as an escape.

BOILERS.

The two oil burning boilers are located front to front in a single fireroom with ample working space between. They are of Thornycroft design and manufacture, oil burning, express type, with one steam drum of 3 feet 6 inches diameter, and two water drums of 22 inches diameter. The heating surface is 2600 square feet each; 1468 cold drawn steel tubes of 1⅛-inch diameter, .116 mils thick, the longest tube is 5 feet 10 11/16 inches; 144 cold drawn steel tubes of 1⅜-inch diameter, .128 mils thick, the longest tube is 6 feet 6⅞ inches. The furnace volume per boiler is 270 cubic feet. The working pressure is 250 pounds.

Boilers are fitted with two Klinger type water gauge glasses, automatic feed regulator, and all other usual fittings. The safety valves are fitted with easing gear which may be operated from outside the boiler room on the main deck. The steam and water drums are covered with from 2 to 3 inches of magnesia lagging, re-inforced with chicken wire, and protected on the water drums with sheet metal, and the steam drum by asbestos cloth.

Each boiler has its own uptake and smoke pipe, with manhole in uptakes, four handholes at base of outer smoke pipe, manholes in steam and water drums, and soot doors in casing for use in inspection and cleaning.

Each boiler has arranged on the front along the bottom three mechanical atomization Thornycroft oil burners, and in the center, over these burners an electric driven Ray Rotary oil burner for port use.

ARRANGEMENT OF THE FIREROOM.

The fireroom is made air tight for closed operation. The oil tanks are arranged outboard on each side of the fireroom with high and low suction to each tank. The suctions may be closed from outside the fireroom on the main deck. The accompanying sketch

indicates the general arrangement of the fireroom. The two steam driven fuel oil service pumps are arranged side by side and take suction through a strainer from the supply main which leads along both sides of the fireroom and one end. Oil can be transferred from any starboard tank to any port tank or vice versa. These pumps discharge through duplicate strainers, oil meter with by-pass, and duplicate oil heaters to burners. There are individual valves to each burner on burner manifold and a quick closing master valve in the supply line. There is a hand driven pump for use in lighting off.

The Ray Rotary burner is located in the center of the boiler front and is supplied with oil by its own pump set, a small rotary pump driven by a chain and motor. There is one Ray burner per boiler and two pump sets. With this burner in use only, the fireroom is opened, and it is not necessary to use any of the main apparatus, only the burner and small pump being in use. This pump discharges through a small oil meter of a size suitable to the amount of oil being used.

The fireroom is built of bullet proof plates where exposed to direct fire, and bullet proof plates also are in way of oil tanks.

There are the usual foam type fire extinguishers and steam smothering line is run around the fireroom close to oil tank bulkhead and also underneath the boilers.

The forced draft blowers are located at the height of the main deck, one on each side, and take suction through a special bullet proof grating. There is a platform built across the fireroom at the height of the main deck with gratings along the sides of the boilers, which gives easy access to boiler fittings, fuel oil heaters, foam fire extinguishers, and lockers for stowage. The fireroom is entered from either side through air lock doors at height of grating. A ladder leads down to floor plates from either side.

MACHINERY AND EQUIPMENT IN FIREROOM.

Two Weir, horizontal, simplex fuel oil service pumps, $5\frac{1}{4} \times 3\frac{1}{4} \times 7$.

Two Kiangnan forced draft blowers, single cylinder, steam driven, reciprocating, forced lubrication. The cylinder is $5\frac{1}{2}$

inches in diameter and a 4½-inch stroke. The fan is 5 feet 3 inches diameter.

Two Weir oil heaters of 60 square feet heating surface each.

Fuel oil suction and discharge strainers in duplicate.

One 1¼-inch Buffalo fuel oil meter in discharge line from main service pump, and one ½-inch Buffalo fuel oil meter in discharge line from pump sets for Ray burners.

Two electric driven rotary fuel oil pump sets, capacity 60 gallons per hour each, ¼ H. P. motor, chain drive, furnished by Ray Manufacturing Co.

Two Ray Rotary fuel oil burners, one per boiler, speed up type, normal rated capacity 20 gallons per hour, motor driven, ¾ H. P.

Six Thornycroft mechanical burners, three per boiler, 700 pounds per hour capacity each.

One two-cylinder hand driven pump for oil supply in starting up, not needed if kerosene generator is in operation as Ray burners can be used.

One pair of tanks for foam type fire extinguishers — 40-gallon capacity.

Vise attached to stanchion in center of fireroom.

Gauge board with pressure gauges, manometer and eight-day clock.

ELECTRIC GENERATOR.

There are two Westinghouse turbo-generators of 25 K. W. capacity each located in the after part of the engine room and one kerosene engine driven 10 K. W. set located on the port side of the engine room all in the vicinity of the main switchboard which is in the port after corner of the engine room. The steam driven sets exhaust to the main condenser, auxiliary condenser or atmosphere and can be operated in parallel. They are of the standard type with reduction gears and the usual governor and safety devices.

The kerosene set is driven by a four-cylinder Universal engine, is fitted with muffler, hand starting, magneto, and gravity feed from a small tank in the engine room. This small tank can be filled from a 210-gallon tank located on the upper deck.

INTERIOR COMMUNICATION.

There are no telephones, but voice tubes are installed as follows:

Size, inches	*From*	*To*
2	Pilot House	Searchlight, forward
2–½	Pilot House	Searchlight, aft
2–½	Pilot House	Engine room
2	Pilot House	Captain Cabin, Radio Room
3	Pilot House	3-inch gun, main deck, aft
2	Engine Room	Boiler room
2–½	Engine Room, Radio Room	Exec. Off. S. R. and Eng. Off. S. R.
2	Engine room	Main deck, Ford. (O-of-D)
2–½	Searchlight, forward	Switchboard, engine room
2	Searchlight, aft	Switchboard, engine room
3	Pilot house, starboard	Machine guns, starboard
3	Pilot house, port	Machine guns, port
2	Captain's cabin, Ward-room	Ship's office

There is a general alarm gong system, 125 volts, with contactor on bridge and in passageway on main deck near the wardroom. Gongs are located in various places throughout the ship.

There are two 500-watt motor generator sets located in engine room for operation of voice tube call bells and other push buttons.

The mechanical systems consist of the engine order telegraph from a double transmitter on bridge to each engine in engine room, a telegraph from the engine room to the fireroom, and the whistle and siren pulls on the bridge.

MAIN SWITCHBOARD.

The switchboard was manufactured by the Portsmouth Navy Yard and consists of three ebony asbestos wood panels supported on angle iron frame work. It is located in the port after corner of the engine room. All switchboard instruments are Westinghouse Electric & Manufacturing Co.

The generator panel has 1-100 ampère, type CN and 2-300 ampère, type CN, circuit breakers; one 0-200 ammeter and two 0-400 ammeters; three 0-150 volt meters; seven 300 ampère, SP., ST., switches, six for meters and one equalizer. At the bottom of the panel is a 500 ampère, DP., DT., switch, not fused, for connecting 10 K. W. kerosene set or the two turbo-generator sets but prevents attempt to parallel.

The distribution panel has two, type CN, circuit breakers and two 0-150 ammeters for searchlights, also one 0-150 voltmeter. There are six 60 ampère, six 30 ampère and three 100 ampère switches for lighting and power distribution.

The other panel is a combination interior communication and distribution panel and has one 0-30 voltmeter and one 0-50 ammeter for 20-volt circuit. There is a switch below the meters for connecting either of the interior communication motor generators. There are three 30 ampère switches connected to 20-volt buses for interior communication purposes and nine 30 ampère switches connected to 125-volt buses for lighting and power distribution.

SEARCHLIGHTS.

One 24-inch high powered searchlight is located on top of the bridge and a similar light aft of the main mast on the deck house. They are fitted for hand control and are of General Electric Company manufacture. The rheostats are located at the main switchboard in the engine room. There is also a 12-inch portable incandescent lamp signaling searchlight which clamps to the rail on top of the pilot house.

LIGHTING.

There are battle lighting and standard lighting circuits. The battle circuits carry lighting in machinery spaces, magazines, at guns and for handling ammunition, searchlights, operating table in sick bay, radio room, pilot house, running, anchor, and signal lights, instrument lights, bracket fans and standing lights. The standard lighting circuits carry all other lighting.

There is a blinker signal set with controller on each side on top of bridge.

All wiring, fixtures, etc., were furnished to Kiangnan Dock & Engineering Works by the Government and are of latest specifications. The work of installation was accomplished by the dock yard and in a very neat manner. The work required was more extensive and of a higher type than any other work the dock yard has previously been called upon to do.

MISCELLANEOUS ELECTRICAL.

A single throw switch is installed in passageway on main deck aft of the engine with leads to switchboard for convenience in hooking up to take light and power from another vessel or from shore. There are wires run into all clothes lockers in officers rooms to supply enough heat to prevent moulding and mildew of clothing during summer months. The sick bay has an electric sterilizer, air lock doors to firerooms are fitted with warning lights with door switches to turn on the lights when doors are opened. Power outlets are installed in the wardroom and wardroom pantry for convenience in using electrical appliances. All staterooms, living quarters, office, radio room, bridge, etc., are fitted with bracket type electric fans.

RADIO INSTALLATION.

The *Guam* and *Tutuila* are equipped with the latest modern radio apparatus. It is conveniently installed in an ample well lighted and ventilated room on the upper deck. The apparatus and equipment in the radio room consists of two transmitters, three receivers, control panel, meters, batteries, and other necessary parts.

There is a desk extending the width of the radio room, about 11 feet, on which the receivers are located.

The batteries are in the corner of the radio room on the deck behind the charging panel and are accessible. The charging panel was manufactured at the Navy Yard, Portsmouth, N. H., of special design to handle all batteries.

There are three antennae as follows: One horizontal, L type, between the masts, consisting of two six wire cages, six inches in diameter for 500-watt transmitter; one single wire for high frequency transmitter which runs from radio room to starboard yard of main mast; two for receivers which runs from entering insulator to topmast forestay.

On top of the radio room two pedestals antenna guards were constructed about seven feet high to extend above awning with insulators on top and at the deck for the transmitting antennae.

The radio motor generator is located about ten feet from the radio room in the passageway on the upper deck between the smoke

pipes. This passageway is protected by a deck above and on the sides sufficiently to protect the motor generator from the weather. This generator serves both transmitters and is of the three unit type. The automatic starter is located near the generator. The generator is approximately 5 feet long, 2 feet high and 2 feet wide.

The apparatus was installed by the dockyard under the supervision of the Government inspector.

Service since installation has been very satisfactory with the exception of minor difficulties which are being taken care of as they appear.

STANDARDIZATION TRIALS.

Place Date	U. S. S. *Guam* Woosung—Yangtze River December 14-15, 1927			U. S. S. *Tutuila* Woosung—Yangtze River February 17, 1928		
	R. P. M.	Speed Knots	I.H.P. Main Engines	R.P.M.	Speed Knots	I.H.P. Main Engines
Group I	135.9	7.48	81	146.3	8.00	119
Group II	187.2	9.86	255	188.8	9.98	257
Group III	226.6	11.39	465	243.6	11.95	597
Group IV	358.4	15.47	2071	320.6	14.47	1375
Group V	360.3	15.62	2048	359.8	15.61	1956

These vessels were designed for 14.5 knots at 320 R. P. M. and from the above data standardization curves were plotted giving results as below. The curves are practically identical — the *Tutuila* curve probably being the better due to better conditions and experience with *Guam*.

Knots	8	9	10	11	12	13	14	14.5	15	15.5
Guam, R.P.M.	146	166	190	216	245	276	307	323	340	358
Tutuila, R.P.M.	146	166	189	216	245	276	306	322	338	356

FOUR-HOUR TRIALS.

The contracts required a four-hour trial at 10 knots to establish guaranteed steaming radius and one at 14.5 knots or not less than 14 knots for guarantee of fuel consumption per square foot of heating surface of boilers. It was not necessary to take water

consumption and the guarantee on speed was to be the average of five high speed runs over the measured mile. Average data taken every fifteen minutes is given below.

The *Guam* left Shanghai early in January of this year on her maiden trip up the Yangtze. She proceeded to Chungking through the gorges at low water, later returned to Hankow, and then soon

	Guam 4 hr. 14.5 kts.	*Tutuila* 4 hr. 14.5 kts.	*Guam* 4 hr. 10 kts.	*Tutuila* 4 hr. 10 kts.
Date	Dec. 16, 1927	Feb. 20, 1928	Dec. 15, 1927	Feb. 18, 1928
Speed, knots	14.43	14.37	10.02	10.04
R.P.M. main engines	321.2	317.5	190.2	190.11
Slip of propeller, per cent	32.6	32.05	20.96	20.74
Displacement, tons	389.8	396.4	401.1	392.5
*Displacement, normal tons	387.0	385.	387.0	385.
*Corresponding draft	5′–3″	5′–2.75″	5′–3″	5′–2.75″
I.H.P. main engines	1395	1361	267	255
Cut off in decimals of stroke	.76–.76–.73	.76–.76–.73	.63–.76–.73	.63–.76–.73
Main steam at boilers pounds gauge	250	247	249	247
Main steam at engines pounds gauge	236	245	240	246

*The difference in displacement and draft is due to the difference obtained on trials in fuel consumption at 10 knots.

again made a trip up the gorges with the American Minister on board. Reports indicate that this class are well designed for the service intended and are the best vessels so far constructed for navigating the river at low water. The officers and crew are pleased with their ship which speaks well for her and for her continued success.

The *Tutuila* left Shanghai for up river in March, proceeding to Chungking, and reports received indicate the same success as was the experience of the *Guam*.

	Guam	*Tutuila*	*Guam*	*Tutuila*
H. P. steam chest, pounds absolute	199	199	75.6	72
I. P. receiver, pounds absolute	79	82.5	29.2	23.5
L. P. receiver, pounds absolute	27.5	25	4.1	4.4
Vacuum, inches	25.6	24.6	25.2	24.8
Barometer, inches	29.85	30.02	29.85	30.02
Main air pump double stroke per minute	20	23	8.1	23
Main circulating pump R.P.M.	326	320	193	175
Main feed pump double stroke per minute	18.6	16.5	9	6.3
F. and B. pump double stroke	26.4	30	23	44
Main injection temperature, degrees F.	55	46.5	55	48
Overboard discharge temperature, degrees F.	81	101	70	93
Outside air temperature, degrees F.	51	43.6	53	47
Engine room temperature, degrees F.	85	74	85	77
Boiler feed from heater, degrees F.	156	150	164	166
Main feed pump discharge pounds gauge	311	270	291	257
Turbo-generator, steam pressure pounds gauge	242.5	243	245	240
Volts	125	125	126	125
Amps	93	90	88.6	82
Kilowatts	11.62	11.25	11.16	10.25
Number of boilers in use	2	2	2	2
Number of burners in use per boiler	3	3	1	1
Square feet of H. S. boiler total	5200	5200	5200	5200
Fuel oil, pounds per hour	3007	2770.5	885.2	781.5
Fuel oil, pounds per I.H.P. main engines	2.16	2.04	3.32	3.06
B.T.U's. per pound (Fuel oil)	19000	19000	19000	19000
Fuel oil, pounds per hour, per square foot H.S.	.578	.533	.17	.15
Air pressure, fireroom, inches water	1.7	1.27	1.04	.6
Boiler, square feet H.S. per I.H.P. main engines	3.73	3.82	19.48	20.4
Fuel oil service pump double stroke per minute	16	13.2	6	4
Fuel oil to heater, degrees F.	73	64	85	84
Fuel oil from heater, degrees F.	141	165	143	172
Fuel oil, specific gravity	.9353	.9353	.9353	.9353
Fireroom temperature above grating, degrees F.	110	104	125	145
Fireroom temperature floor plates, degrees F	92	85	108	109
Pressure fuel oil to burners pounds gauge	184	134	120	100
R.P.M. blowers	431	356	298	224

MARINE DEVELOPMENT OF PULVERIZED COAL.

By *Comdr. J. S. Evans, U. S. N., Member,

AND

†R. C. Brierly, Associate Member.

Among the cargo vessels owned or operated by the United States Shipping Board, Merchant Fleet Corporation, are some which have been converted from steam to Diesel motor ships, but by far the greater number are still steam vessels, some burning oil and others coal. Both types, Diesel and steam, have their disadvantages. Conversion from steam to motor drive is a costly procedure. A motor ship cannot always find in any port the supply of spare parts which sometimes seems necessary; the oil burning steam vessel must contend with the increasing cost of fuel oil and the difficulty of procuring good grades in many parts of the world. Steam vessels, with hand fired coal furnaces have the difficulty of finding suitable men to handle the fires efficiently.

Many steam vessels are equipped with water tube boilers, but a very large number are equipped with Scotch marine boilers. Although the disadvantages mentioned above for steam vessels apply to vessels equipped with either type of boiler, the Scotch marine boiler appears to have a slight advantage over the water tube boiler in that it can withstand rougher handling by unskilled personnel than can the water tube boiler. The Scotch boiler is, except for its weight, an economical boiler, when properly operated, and the results secured from it when fired with fuel oil by suitable mechanical atomizers have been very good. The results when hand fired with coal over the range of combustion rates usually used, however, have been only fair. The overall boiler and furnace efficiencies reached with expert and conscientious firemen seldom have exceeded sixty-five per cent, and there has been

* Officer-in-Charge, Fuel Oil Testing Plant, Navy Yard, Philadelphia, Pa.
† Lt.-Comdr. (E. V.), U. S. N. R. Associate Mechanical Engineer, Fuel Oil Testing Plant, Navy Yard, Philadelphia, Pa.

a marked decline from this percentage at higher rates of combustion where the fuel oil burners still show good results. Expert and conscientious firemen are not only hard to find and difficult to keep — such men are usually not content to remain as firemen but desire promotion to better jobs — but when they are obtained can not always, though willing, keep up excellent fires throughout an entire voyage, particularly in the tropics.

The Fuel Conservation Section of the Shipping Board for a number of years has been vitally interested in the problem of burning pulverized coal with the idea of getting away from the cost of Dieselization, from the increasing cost of fuel oil, and from the large personnel problem connected with hand-fired coal burning boilers. The Board decided to conduct tests to ascertain whether or not such use of coal was feasible on board ship. It was decided to make the tests on a Scotch marine boiler because the use of pulverized coal in the small water cooled furnaces of these boilers seemed to offer a more difficult problem than its combustion in the refractory lined furnaces of water tube boilers. In the latter boiler the walls and floors act as heat reservoirs and greatly assist in maintaining the ignition temperature of the combustible.

The first test made by the Board was made at Chester, Pa., using the conventional stream-line burner. The results were not all that were anticipated, but were sufficiently promising to warrant further tests.

At this time the Fuel Conservation Committee at the instigation of its chairman, Captain C. A. McAllister, who was ably backed by Captain R. D. Gatewood (CC), U. S. N., and Mr. C. J. Jefferson of the Fuel Conservation Section of the Board, decided to request the cooperation of the Navy Department in these tests. The result of such request was that the Bureau of Engineering of the Navy Department authorized the Fuel Oil Testing Plant to conduct tests of such equipments as the Board desired or that seemed adaptable for use on board ship.

The Fuel Oil Testing Plant is a laboratary maintained at the Navy Yard, Philadelphia, Pa., by the Bureau of Engineering. It started to function in the early days of burning fuel oil in the Navy, and is so named because, originally, practically all the work done was in connection with fuel oil and fuel oil burners. Its

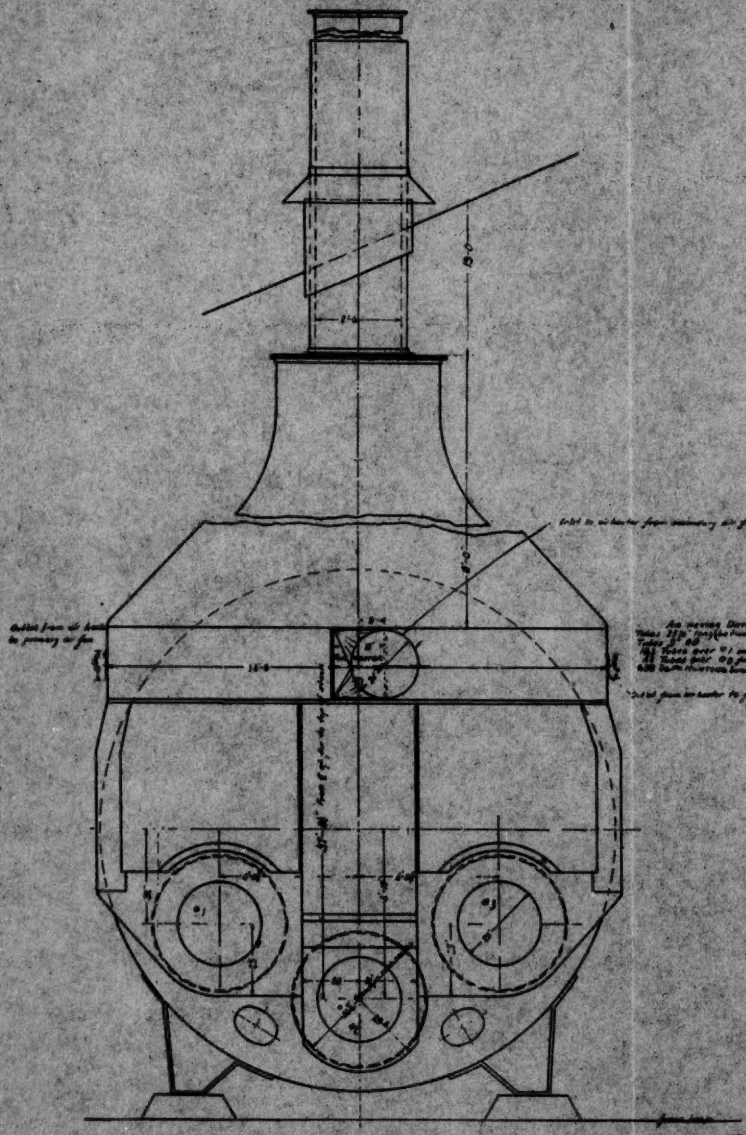


Fig.

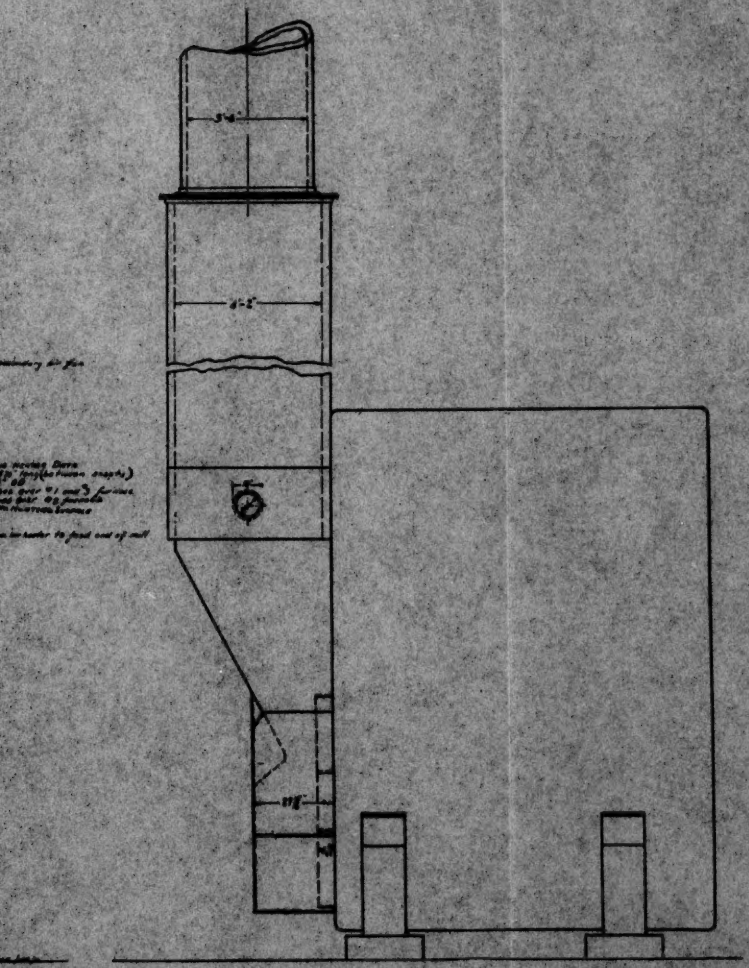


Fig. 1.

duties have, however, been added to from time to time until at present practically every device used in the fireroom of a Naval vessel is subject to test at the Plant. This includes boilers, oil burners, oil pumps, viscosity regulators, oil separators or purifiers, water level regulators, draft gauges, and fire and insulation brick. The work done by this Plant particularly in the advancement of the art of burning fuel oil under marine boilers, in the development of oil burners, and in raising the standards for refractories has resulted in many economies not only for the Navy but also for the Shipping Board. The Board has benefited in many instances because it has followed Navy practice in so far as concerns purchasing only those materials that have been shown, by test at this Plant, to be suitable. It was, therefore, logical for the Board to desire that the tests on pulverized coal be made here.

It was decided, as a result of discussions between representatives of the Fuel Conservation Committee and officers of the Fuel Oil Testing Plant, before starting any tests, that the only equipment or installations to be tested would be those operating on the so-called "unit system." A "unit system" is one in which the coal is pulverized continuously immediately before passing to the burners, thus avoiding the dangers of the "bin system" in which coal is pulverized, conveyed to storage, and drawn from as needed. The "bin system" is, at this time, impractical for ship installations because of difficulties encountered in maintaining bunkers gas-tight as well as dust-tight — as in order to avoid any possibility of spontaneous combustion it would be necessary to keep such bunkers full of some inert gas.

A Scotch marine boiler, which had been removed from one of the Board's vessels, had been installed at the Fuel Oil Testing Plant some years before for use in oil burner tests for the Board and in instructing the engineering personnel of the various vessels of the Fleet Corporation in the burning of fuel oil. A sketch of this boiler, with the air heater and double front as installed after the first series of test runs is shown in Figure 1. The principal particulars of this boiler as originally installed are as follows:

Total boiler water heating surface, square feet	2555
Inside diameter, feet and inches	14–9
Overall length of boiler, inches	132

Distance between tube sheets, inches	84 14/32
Working Pressure, lbs. per square inch gauge	200
Number of furnaces	3
Diameter of furnaces at bottom of corrugations, inches	43
Length of furnaces, feet	7
Furnace heating surface total, square feet	270
Number of ordinary tubes	270
Number of stay tubes	94
Total number of tubes	364
Inside diameter of ordinary tubes, inches	2 3/4
Inside diameter of stay tubes, inches	2 3/8
Total number of tubes from each wing combustion chamber	122
Total number of tubes from central combustion chamber	120
Tube heating surface, square feet	2015
Inside distance back to front of combustion chambers, inches	34
Total combustion chamber heating surface, square feet	270
Volume of each furnace and its combustion chamber without any brickwork, cubic feet	161
Total volume of the three furnaces and combustion chambers without any brickwork, cubic feet	482.9

All tubes were equipped with retarders at the ends contiguous to the combustion chambers.

The Fuel Conservation Committee then entered into discussions with various manufacturers to enlist their cooperation in the tests. These firms were to furnish — without cost — equipment for test, together with the services of engineers as their representatives to consult with the Fuel Conservation Committee and the Fuel Oil Testing Plant. Several companies were much interested and one of them furnished all the equipment for the first test, such equipment including the pulverizer, primary air fan, and the burners.

This equipment was selected primarily because the burners were of the type designed to maintain turbulent, rather than stream-line, flow of coal into the furnaces; thus this installation would furnish a comparison with the results of the stream-line burner used in the Chester tests.

The installation of this equipment was completed early in 1926. Figure 2 shows the general arrangement of the apparatus. The burners as originally supplied by the manufacturer had no provision for lighting off other than by the use of torches. They were, therefore, modified by the Plant by the installation of fuel

oil burners in the center of each furnace front. Figure 3, which is a photograph of the boiler front, shows such oil burner in place in furnace No. 3. The photograph shows the large amount of piping leading to each furnace, giving an idea of the trouble which could be expected in distributing the fuel equally to each burner of each furnace, and more so to each tuyere of the individual burners.

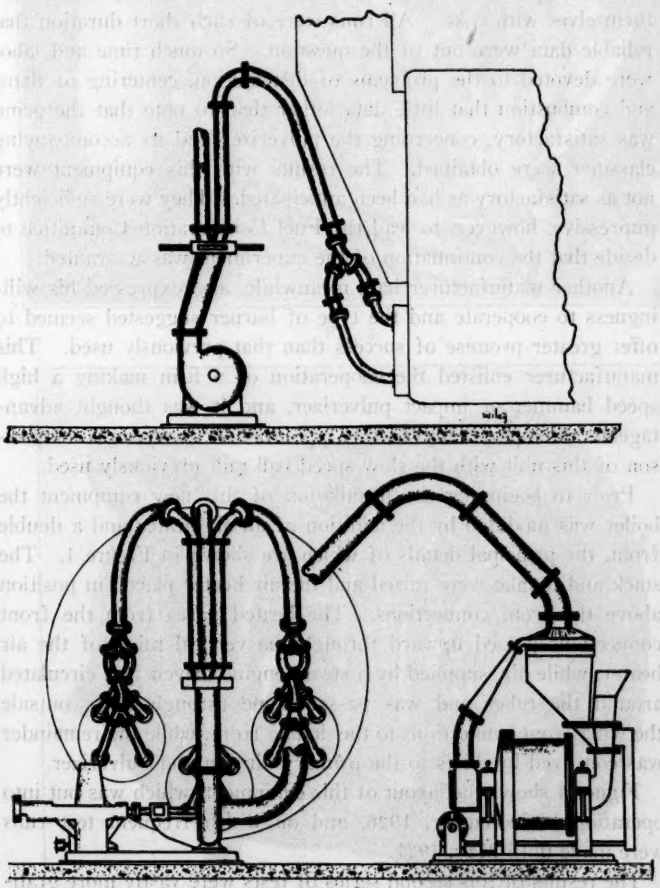


Fig. 2

A number of test runs were made during the summer of 1926 but in October of that year the entire equipment was removed and returned to the manufacturer, at his request, for further research and development.

During these runs considerable trouble was experienced with the burners and the distribution of coal to them. The burner lines often plugged solidly with coal and the burner tuyeres blocked themselves with coke. All runs were of such short duration that reliable data were out of the question. So much time and labor were devoted to the problems of distribution, centering of flame and combustion that little data, other than to note that the grind was satisfactory, concerning the pulverizer and its accompanying classifier were obtained. The results with this equipment were not as satisfactory as had been anticipated. They were sufficiently impressive, however, to lead the Fuel Conservation Committee to decide that the continuation of the experiment was warranted.

Another manufacturer had, meanwhile, also expressed his willingness to cooperate and the type of burner suggested seemed to offer greater promise of success than that previously used. This manufacturer enlisted the cooperation of a firm making a high speed hammer or impact pulverizer, and it was thought advantageous to employ a mill of this type in order to obtain a comparison of this unit with the slow speed ball mill previously used.

Prior to beginning the installation of this new equipment the boiler was modified by the addition of an air heater and a double front, the principal details of which are shown in Figure 1. The stack and uptake were raised and the air heater placed in position above the front connections. The heated gases from the front connections passed upward through the vertical tubes of the air heater, while air, supplied by a steam engine driven fan, circulated around the tubes and was passed some through ducts outside the wing front connections to the double front, while the remainder was conveyed by ducts to the primary air fan and pulverizer.

Figure 4 shows the layout of this equipment, which was put into operation in December, 1926, and on which frequent test runs were made until May, 1927.

The results of this second series of tests were vastly more gratifying than were those of the first series, especially as the troubles

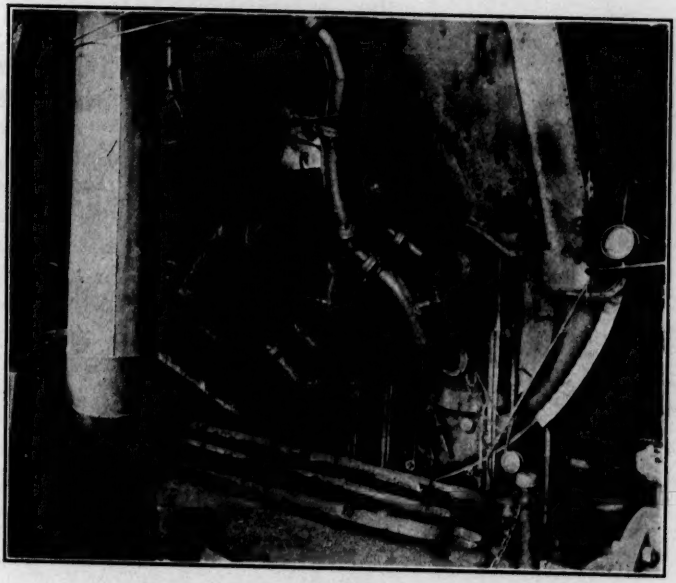


FIG. 3.

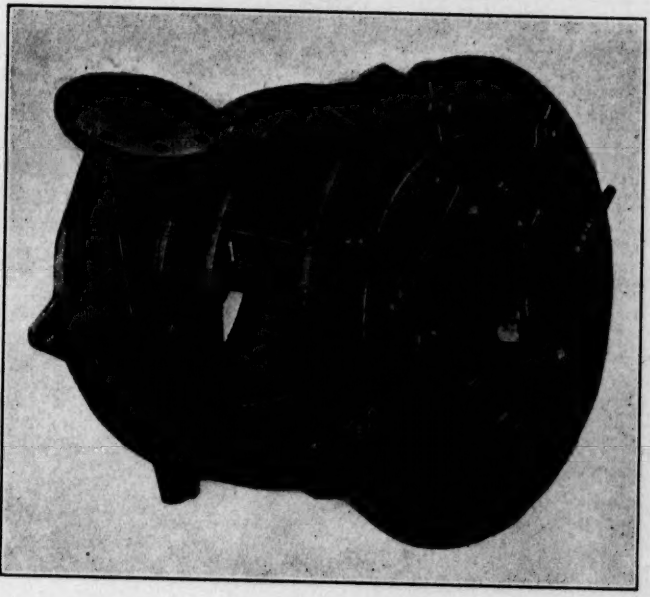


FIG. 5.

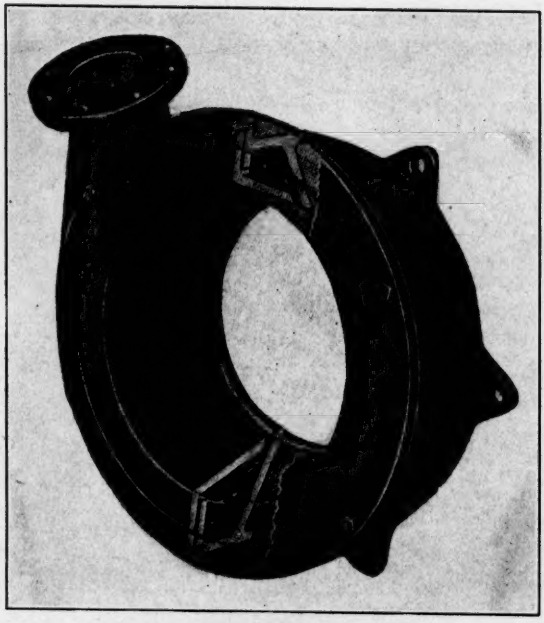


FIG. 6.

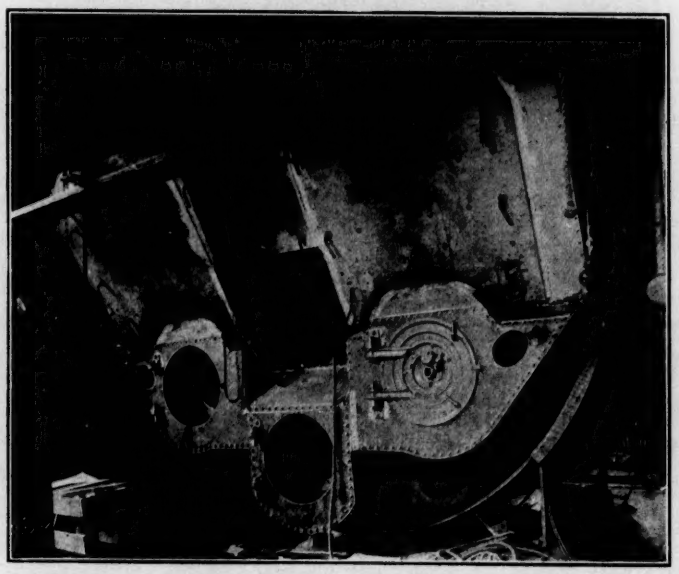


FIG. 8.

which had been encountered with the burners in the earlier series were noticeable by their absence in the second series. As a matter of fact where maintaining combustion had been a hard problem in the first tests, with distribution a close second, the hard problems of the second series were (1) obtaining a fineness of product which could be expected to give good results in the small furnace volume, (2) satisfactory regulation of primary air at the mill and (3) distribution as affected by (1) and (2).

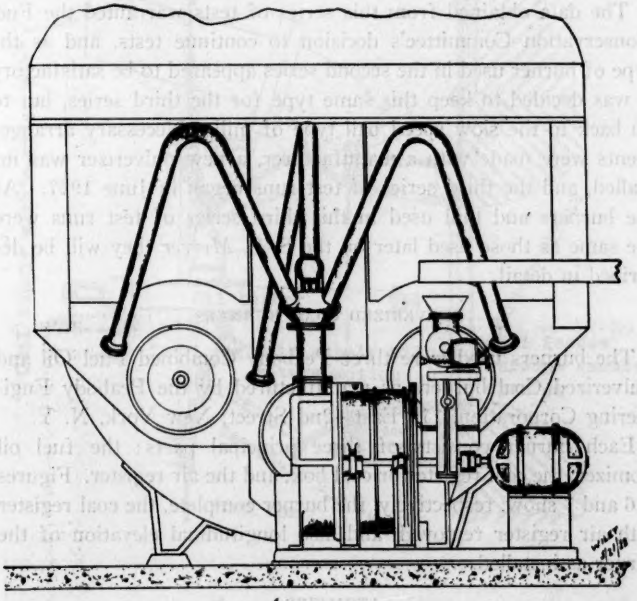


Fig. 4.

It was found that when the burners were furnished with coal of such a degree of fineness that combustion could be maintained such combustion would also be completed in the short flame travel that was permissible. It was found, however, that the pulverizer as furnished did not give a product as fine as that given by the pulverizer used in the first tests and that such product varied

(1) with the quality of the coal, (2) with the method of admission of air to the mill, (3) with the amount of coal used per hour, and (4) slightly with the clearances between the fixed and moving parts. All changes suggested by the manufacturer were made to the mill but in spite of such changes the product of the mill was not of the fineness necessary for efficient burning in the small furnaces of a Scotch boiler which allow only short flame travel. This pulverizer was removed, May 1927, and returned to the manufacturer, at his request, for further development.

The data obtained from this series of tests warranted the Fuel Conservation Committee's decision to continue tests, and as the type of burner used in the second series appeared to be satisfactory it was decided to keep this same type for the third series, but to go back to the slow speed ball type of mill. Necessary arrangements were made with a manufacturer, a new pulverizer was installed, and the third series of test runs began in June 1927. As the burners and mill used in this third series of test runs were the same as those used later on the S. S. *Mercer* they will be described in detail.

PULVERIZED COAL BURNERS.

The burners used were three Peabody Combined Fuel Oil and Pulverized Coal burners as manufactured by the Peabody Engineering Corporation, 110 East 42nd Street, New York, N. Y.

Each burner consists of three principal parts: the fuel oil atomizer, the coal register or coal box, and the air register. Figures 5, 6 and 7 show, respectively, the burner complete, the coal register with air register removed, and also longitudinal elevation of the burner as installed.

ATOMIZER.

A mechanical pressure atomizer of the Peabody-Fisher Wide Range Type is used for fuel oil. This is ordinarily used for lighting off the coal, but may be operated, with the air register, as a fuel oil burner. The atomizer can be readily withdrawn from the register after use in lighting off coal; the quick detachable yoke at the fireroom end of the atomizer barrel allows it to be entirely removed or replaced at will.

COAL REGISTER.

Pulverized coal is conveyed by its carrier air via the feeder pipe to the coal register or coal box, which consists of an involute casting of rectangular cross section, having an annular opening which slopes slightly toward the furnace and encircles the burner throat,

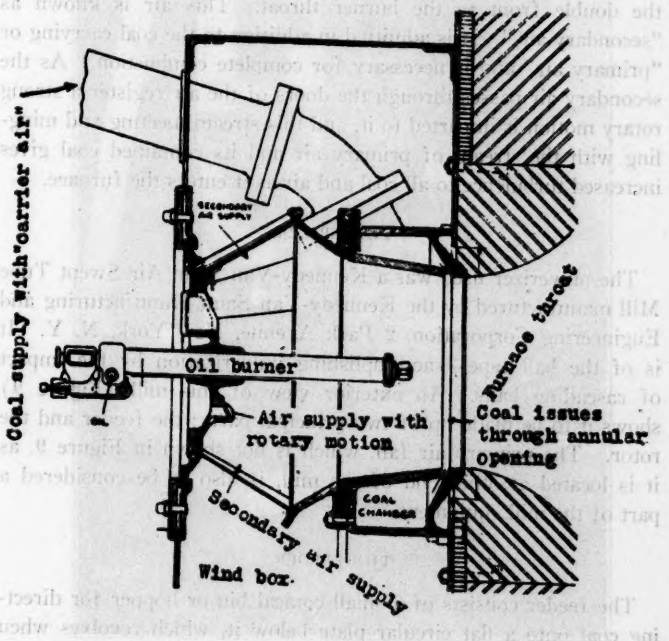


Fig. 7.

as shown in Figure 7. The involute shape of the casting causes a relatively uniform mixture of air and coal dust to pass from this slot through the refractory furnace opening ring, forming a venturi shaped veil of coal.

AIR REGISTER.

The air register is a large hollow truncated cone consisting of curved adjustable doors or louvres hinged to studs equidistantly disposed and secured to the burner front plate which is hinged to — and forms a door in — the double front, as shown in Figure 8. The function of the air register is to control the flow of air from the double front to the burner throat. This air is known as "secondary air." It is admitted in addition to the coal carrying or "primary air" and is necessary for complete combustion. As the secondary air passes through the doors of the air register a strong rotary motion is imparted to it, and this stream meeting and mingling with the stream of primary air and its contained coal gives increased turbulence to all coal and air as it enters the furnace.

PULVERIZER.

The pulverizer used was a Kennedy-Van Saun Air Swept Tube Mill manufactured by the Kennedy-Van Saun Manufacturing and Engineering Corporation, 2 Park Avenue, New York, N. Y. It is of the ball type — accomplishing pulverization by the impact of cascading balls. An exterior view of this mill (Figure 9) shows it to be made up of two principal parts: the feeder and the rotor. The primary air fan, which is not shown in Figure 9, as it is located at other end of the mill, is also to be considered a part of the mill equipment.

THE FEEDER.

The feeder consists of a small conical bin or hopper for directing coal onto a flat circular plate below it, which revolves when the feeder is in operation. The coal is prevented from falling off by a stationary band about three inches high which encompasses 330 degrees of the upper surface of the disc; the remaining 30 degrees arc provides space for coal to leave the disc. The amount spilled off is regulated by an adjustable "knife" along which the coal passes, descending from the edge of the disc into a shute leading to the rotor entrance. The rate of coal feed is a function of the speed of rotation of the disc — driven by a variable speed motor — and the knife adjustment.

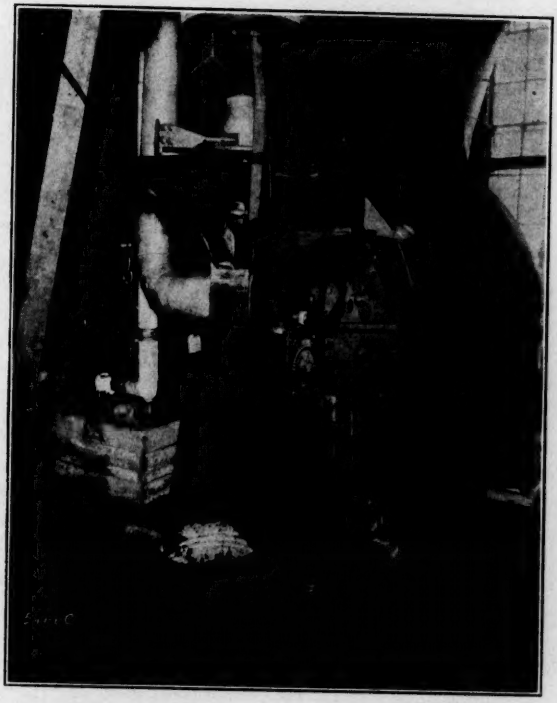


FIG. 9.

THE ROTOR.

The rotor is constructed of two cylinders, the inner being made up of corrugated sections secured to the outer; layers of sound deadening insulation fill the space between the inner and outer cylinders and the outer cylinder is also lagged with heavy layers of hair felt and linoleum.

The entrance to and exit from the interior of the rotor are formed by hollow journals made integral with the header plates bolted onto the ends of the outer cylinder. The interiors of both journals are machined to form hollow truncated cones with their bases toward the rotor; they are provided with square screw threads devised to prevent balls or partially ground coal from leaving the rotor. The exit opening is also provided with a coarse mesh screen for the same reason. The journals, supported by massive bearings, carry the rotor and allow it to turn freely.

The flange securing the outer cylinder to the header plate of the discharge end of the rotor is encircled by a herring-bone gear which meshes with a pinion, driven — through a Poole speed reduction unit — by a steam turbine manufactured by the Carling Turbine Blower Co., Worcester, Mass.

The grinding charge of the mill, which is put into the inner cylinder of the rotor by way of the feed shute, consists of about five thousand pounds of balls of various sizes. The steel used is of special erosion resisting quality. "Tramp iron" or other metal entering the rotor adds to the pulverizing charge without harm. Magnetic separators are unnecessary with coal pulverizing ball mills.

PRIMARY AIR FAN.

After pulverization the coal is drawn out of the rotor by a fan which is known as the primary air fan because it furnishes the coal carrying, or primary, air. The fan as supplied by the manufacturer was a duplex one driven by a five horsepower variable speed motor. Both the fan and its housing were divided by plates into two sections taking suction from the center on opposite ends and discharging vertically. This construction was used because it was thought desirable to draw a rich mixture of coal and air from

the mill and dilute this on delivery with additional air from the opposite side of the fan. It was early found that good mixing did not result by use of this arrangement; better results were obtained by conducting heated air into the space between the discharge journal of the mill and the mill-end of the fan, the opposite end being blanked off. The major portion of the primary air was supplied in this manner during the runs described below; a very small quantity being passed through the mill to cause an even flow of pulverized coal.

Description of the coal and water weighing apparatus, pumps, indicators and recorders used is not included in the present article; it suffices to say that the instruments installed were carefully calibrated and ample for the ascertainment of all pertinent data. During all operation the boiler pressure was maintained at 180 pounds per square inch gauge by a hand operated bleeder valve; steam in excess of that used by plant auxiliaries was blown off at constant pressure to the atmosphere.

PULVERIZED COAL SAMPLES.

Pulverized coal samples were taken at regular intervals from the pulverized coal duct above the primary air fan. Two 1-inch I. D. sampling tubes graduated in inches were arranged to slide at right angles to each other across the duct. The tubes were allowed to remain one minute at each inch mark while the coal was collected in a vacuum bag. The samples taken from the two tubes were mixed, quartered, and stowed in sealed containers until screened. Coal samples for analysis were obtained by taking a 300-cubic centimeter scoopful from the coal scale hopper prior to the passage of the coal to the feeder. Suitable composites of these samples were obtained and packed in air tight cans. Analyses were made by the Bureau of Mines (Department of Commerce) and also by the Fuel Oil Testing Plant.

After a large amount of preliminary work devoted to ascertaining the effect of all variables between their respective limits, it was decided — in the latter part of July 1927 — that the "unit system" consisting of the burners and pulverizer, as described above, were suitable for trial on a run of long duration. Figure 10 shows the

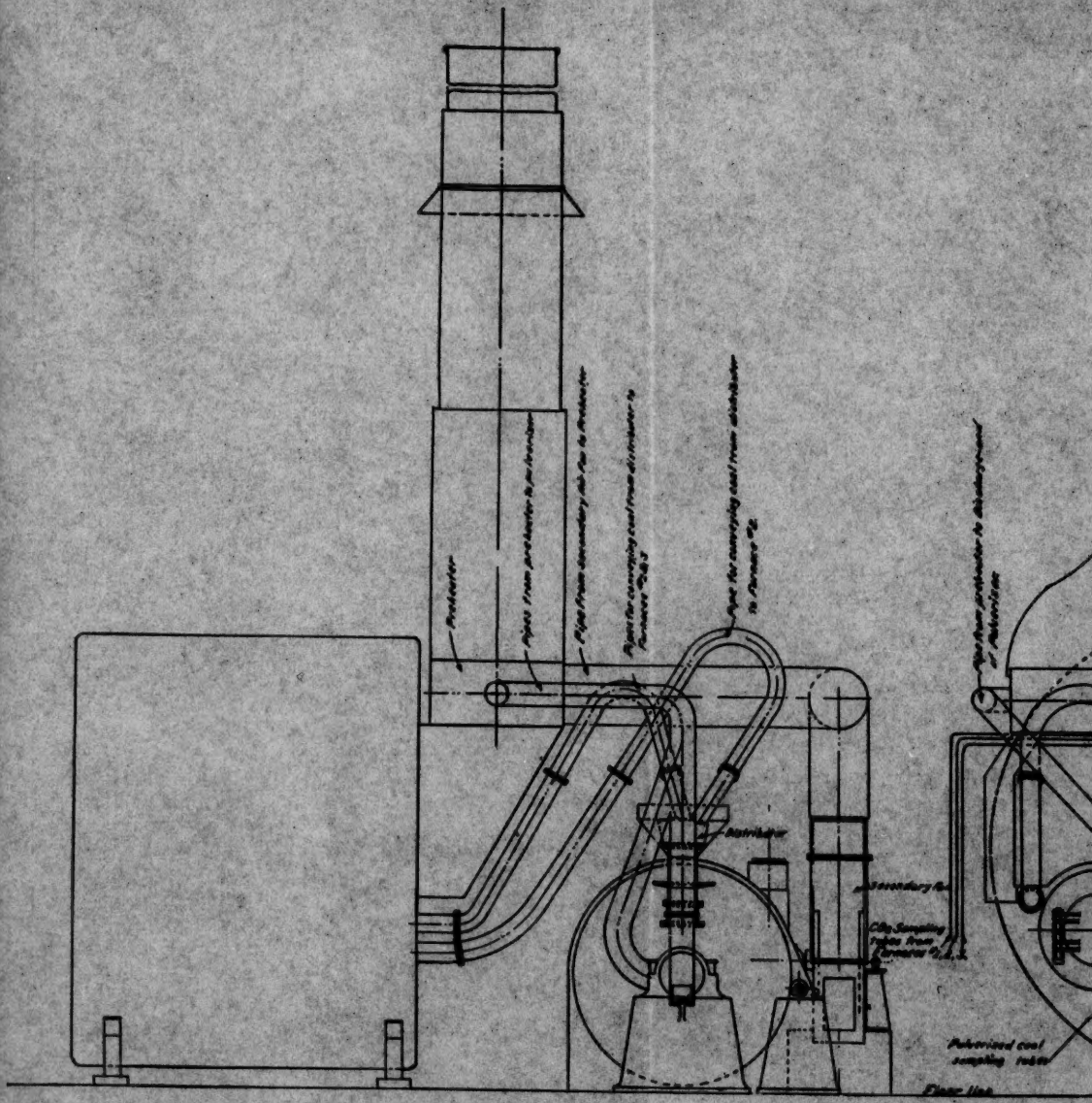
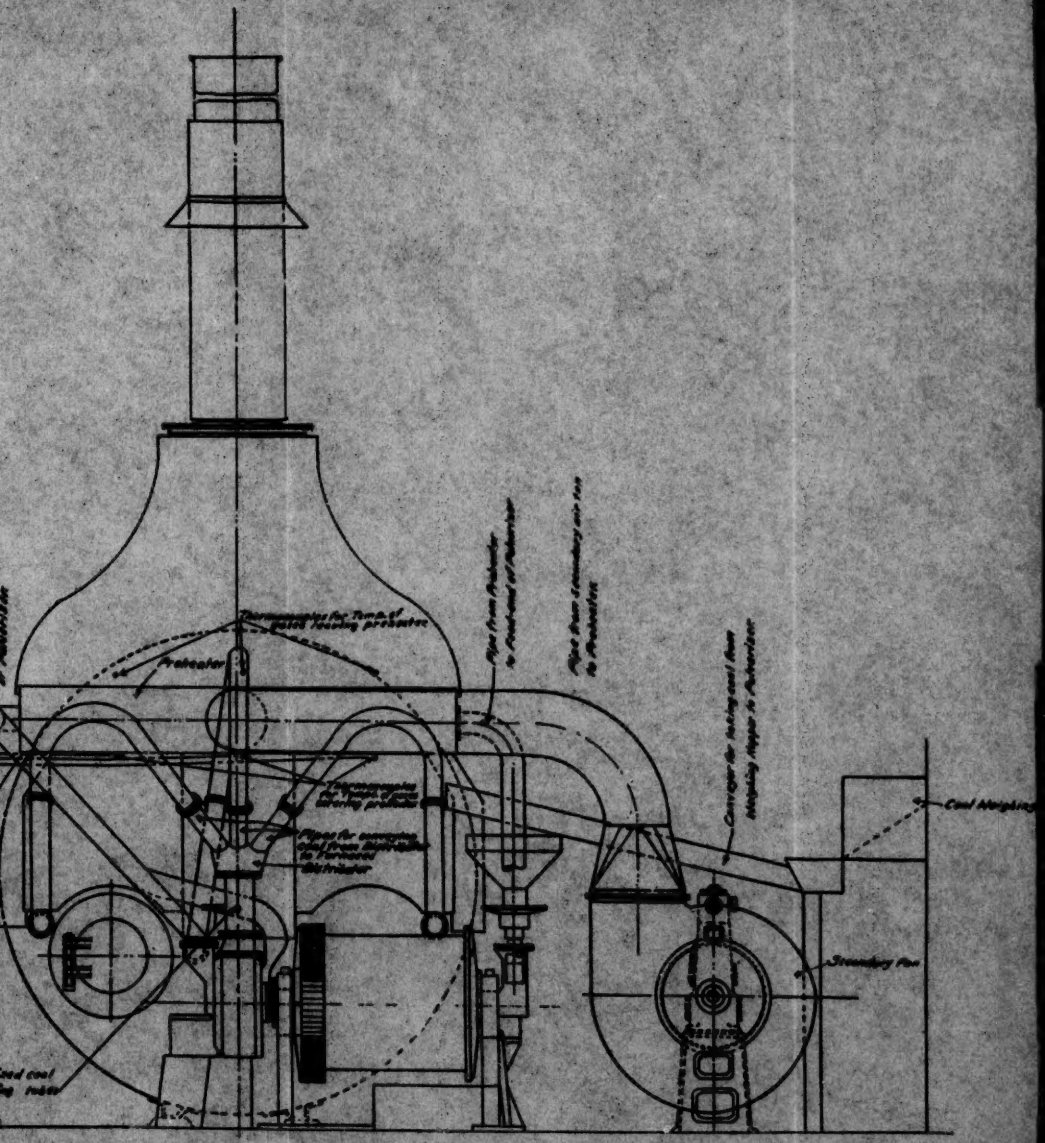


Fig. 10.



16.

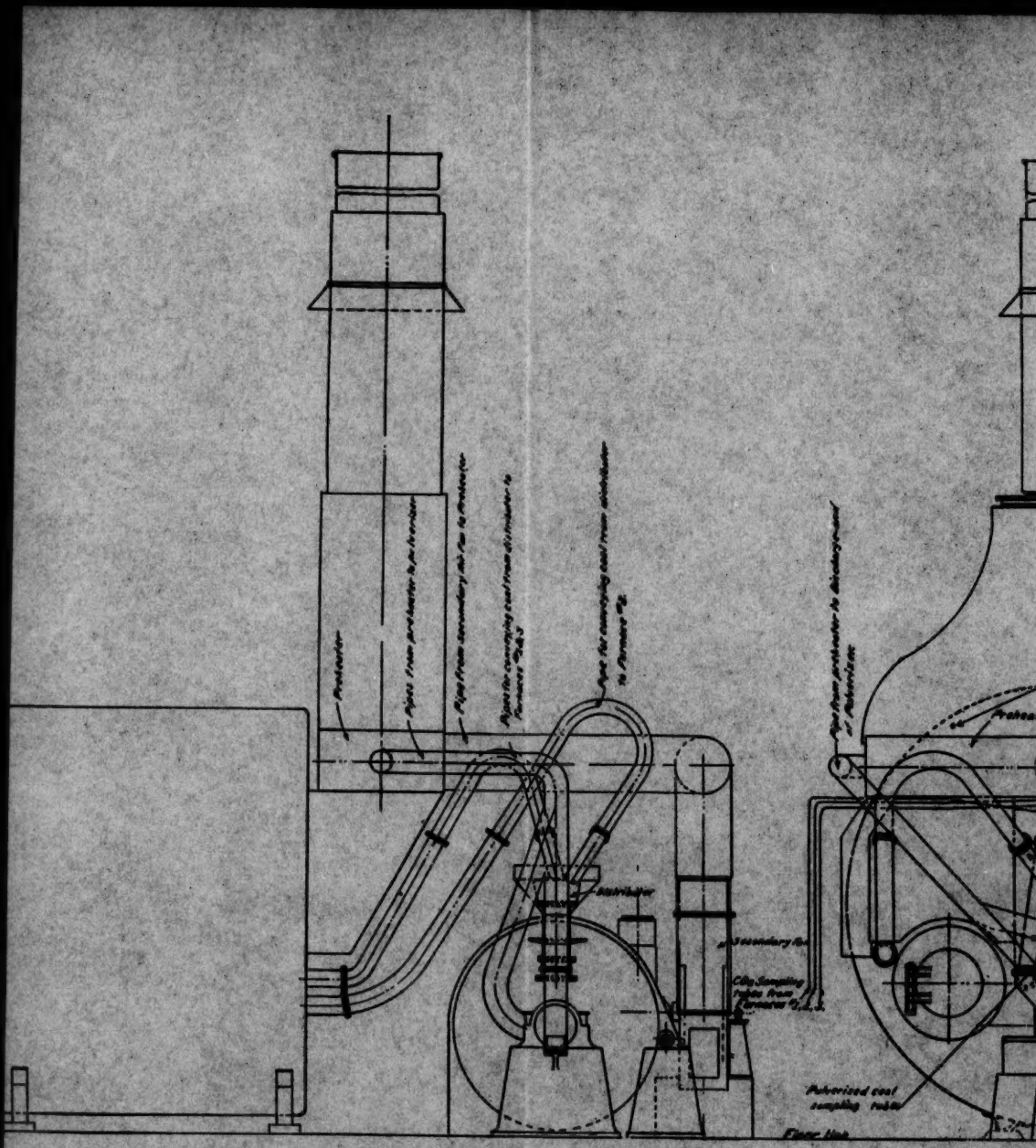
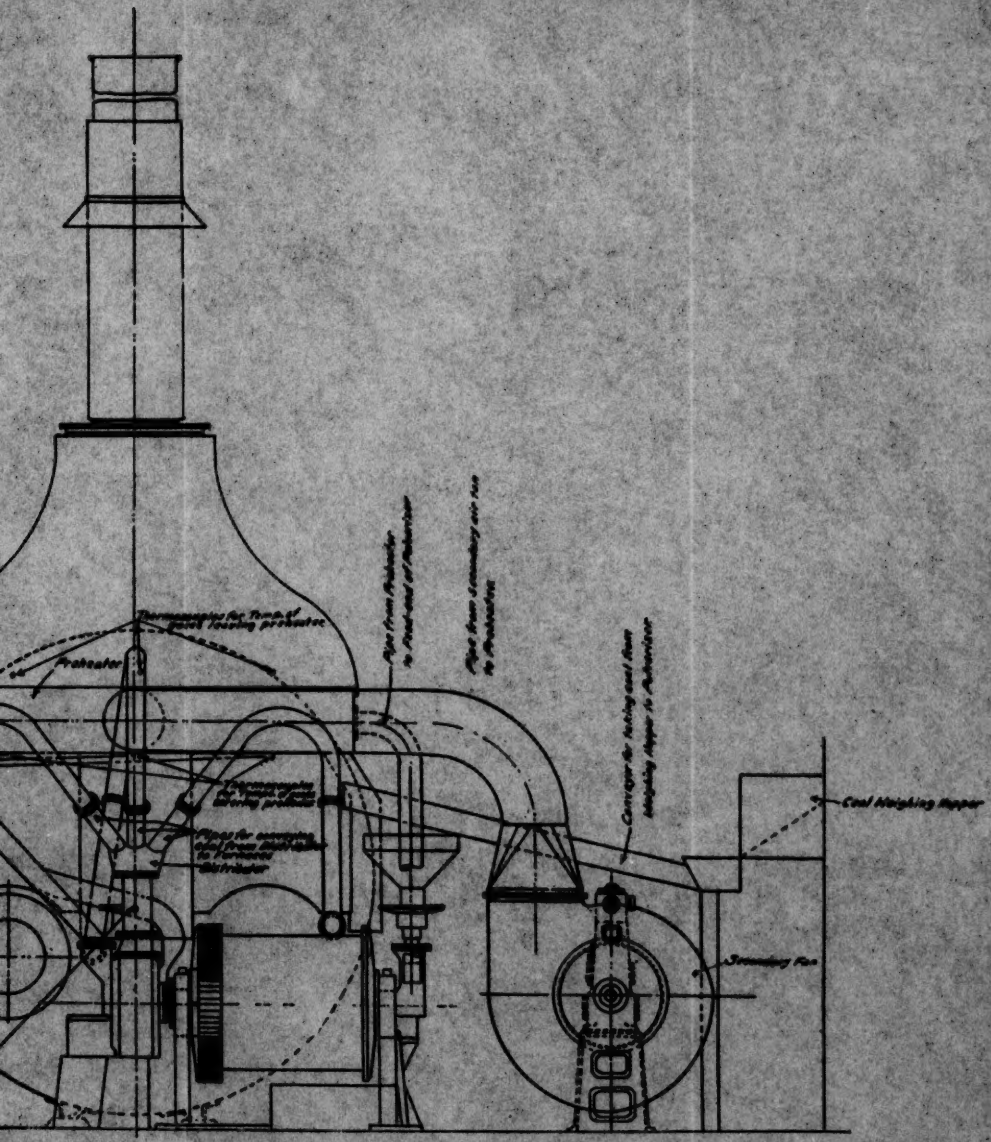

Pulverizer
Pipe from pulverizer to burner
Pipe for conveying coal from pulverizer to burner No. 2
Pipe for conveying coal from pulverizer to burner No. 3
Pipe from pulverizer to pulverizer
Pulverizer
Pipe from pulverizer to pulverizer
Pulverizer
Distributor
Secondary air
Coal sampling holes from Pulverizer
Pulverized coal sampling holes
Floor line

Fig. 10.


Preheater
Coal Weighing Hopper

third installation as used on this long run and the preliminaries which immediately preceded it. In the interval between March 1926 — when the first pulverized coal installation at the Fuel Oil Testing Plant was completed — and July 1927, two types of burners and three pulverizers had been tested, nearly one hundred runs had been made, and much time had been devoted to calculation, coal analyzing, and careful study of results only a small portion of which are considered here.

A thorough analysis of even the major details of the knowledge gained during this period is impossible in the space of this monograph. Three of the variables which proved the most important, however, were: (1) coal grind, (2) equal distribution of pulverized coal to the furnaces, and (3) air admission to the pulverizers used, which affected both the grind and distribution.

During the early runs with the second pulverized coal installation used, it was observed that the appearance of the flame was greatly affected by the fineness of the coal. The finer the grind the shorter and more rapid burning were the flames which were obtained at any given combustion condition and superior intermixture of the air with the coal particles was obtained. Coarse grind of coal caused the flames to be long and slow burning with many particles of coal striking the furnace corrugations and becoming chilled before their combustion was completed. When even small percentages of pulverized coal failed to pass through screens of 40-mesh per square inch, the flames were characterized by bright streaks each streak being the path of a large sized particle of coal. On account of their appearance these large burning particles were nicknamed meteors. It was later found that these large particles after becoming chilled by encountering some relatively cold surface, fell in the furnaces as hollow globules sometimes 1/16 inch to 3/32 inch in diameter. When viewed under a microscope these coal bubbles are seen to have numerous shiny facets resembling fragments of highly polished jet. Touching these bubbles with a needle point causes them to disintegrate into powder.

In all instances where steady conditions were maintained finely ground coal produced overall boiler efficiencies greatly superior to those obtained when the grind was relatively coarse.

The importance of fineness of grind may be summarized briefly as follows: the smaller the particles of coal powder, the more rapidly combustion takes place; larger particles — requiring more time, and consequently space in which to completely burn — are apt to be cooled below the ignition temperature prior to the liberation of their full calorific value, also adding to the deposits in the furnaces and uptakes.

The hardness and friability of the coal fed to any mill have naturally a great effect upon the fineness of grind produced; the rate at which the coal is passed through the mill, the weight of the hammers and the clearances in the hammer type mill, the weight

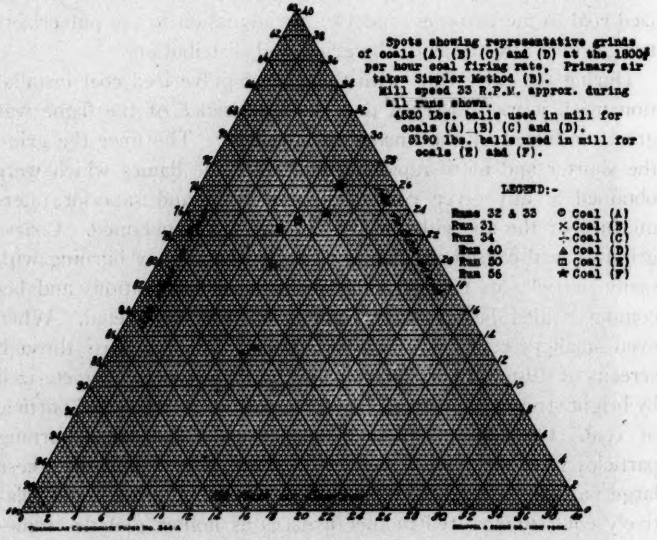

Spots showing representative grinds of coals (A) (B) (C) and (D) at the 1800# per hour coal firing rate, Primary air taken Simplex Method (B).
Mill speed 33 R.P.M. approx. during all runs shown.
4520 Lbs. balls used in mill for coals (A) (B) (C) and (D).
5190 lbs. balls used in mill for coals (E) and (F).
LEGEND:-
Runs 32 & 33 ⊙ Coal (A)
Run 31 × Coal (B)
Run 34 ÷ Coal (C)
Run 40 △ Coal (D)
Run 50 □ Coal (E)
Run 56 ★ Coal (F)

Fig. 11.

of the ball charge in the ball type mill, and the method of introducing air to the mills and primary air fans are also vital factors.

The speed at which the mill is operated has great bearing on the fineness of grind. This was maintained constant (1800 R. P. M.) with the impact or hammer mill used in the second installation, as this mill was driven by a constant speed motor. With the Ken-

nedy Pulverizer used in the third installation, the speed varied somewhat owing to the variations of the governor of the driving turbine, but endeavor was made to hold the speed constant at that point which gave the best grind.

The effect on fineness of grind, due solely to the character of the coal — with all other variables, except rate, maintained constant — is shown in the triangular chart of Figure 11. The five coals used were all Cambria County, Pennsylvania, semi-bituminous, but each was from a different mine operated by a separate company.

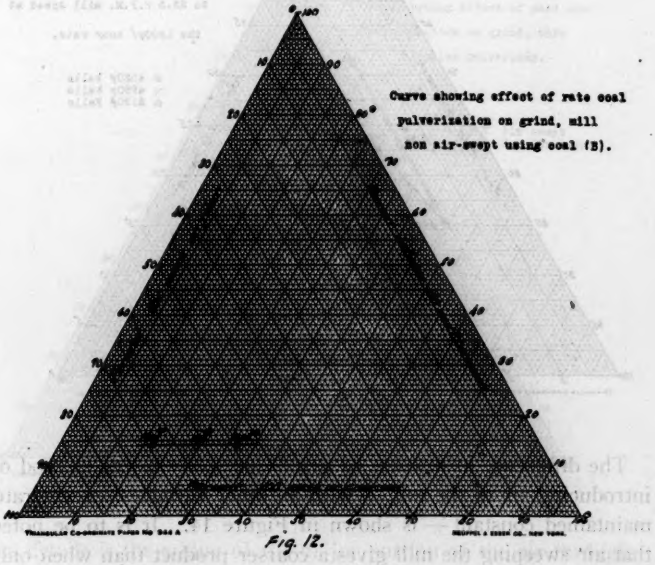


Fig. 12.

The effect on fineness of grind due solely to the coal rate — with all other variables maintained constant — is shown in the triangular chart Figure 12. The numbers 1200, 1600 and 1800 are the number of pounds of coal per hour passed through the mill. It is to be noted that, in this instance, one of the percentages remained constant while the other two varied.

The difference in the fineness of grind due solely to ball charge — with all other variables, except rate, maintained constant — is shown in the triangular chart Figure 13. It is to be noted that for a given mill speed the weight of the ball charge with balls of a certain size is very critical.

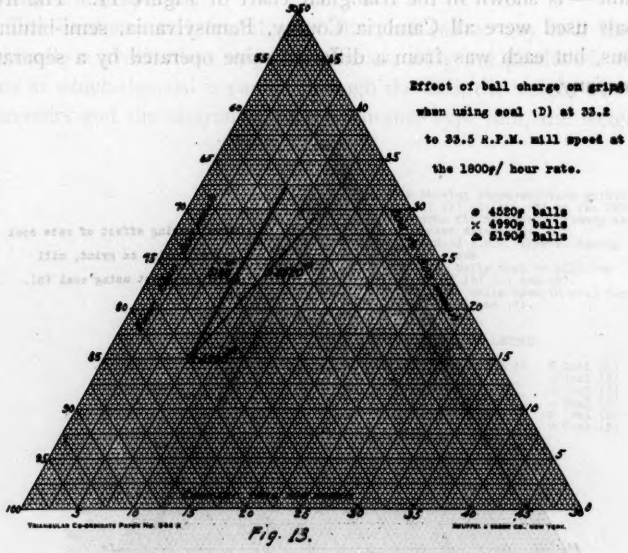

Effect of ball charge on grind
when using coal (D) at 33.2
to 33.5 R.P.M. mill speed at
the 1800#/ hour rate.
● 4820# balls
× 4990# balls
▲ 5190# Balls

Fig. 13.

The difference in fineness of grind due solely to the method of introducing air to the mill — with all other variables, except rate, maintained constant — is shown in Figure 14. It is to be noted that air sweeping the mill gives a coarser product than when only sufficient air to insure steady flow to the primary air fan is used and the major portion taken through the primary air fan without passing through any part of the mill proper. It is also to be noted that change in rate produces greater change in fineness when air sweeping the mill than when not air sweeping it.

The effect of change in speed in the Kennedy Ball Mill — all other variables, except rate, maintained constant — is shown in

Figure 15. It is to be noted that the speed of the mill for a given ball charge is quite critical.

Consideration of these charts, Figures 11 to 15, inclusive, shows that obtaining maximum fineness of grind for any given coal rate with any one coal depends largely on maintaining the following variables as nearly constant as possible: (1) ball charge at its most effective grinding weight and ball size; (2) speed, at the most efficient R. P. M. for grinding. Even more important than

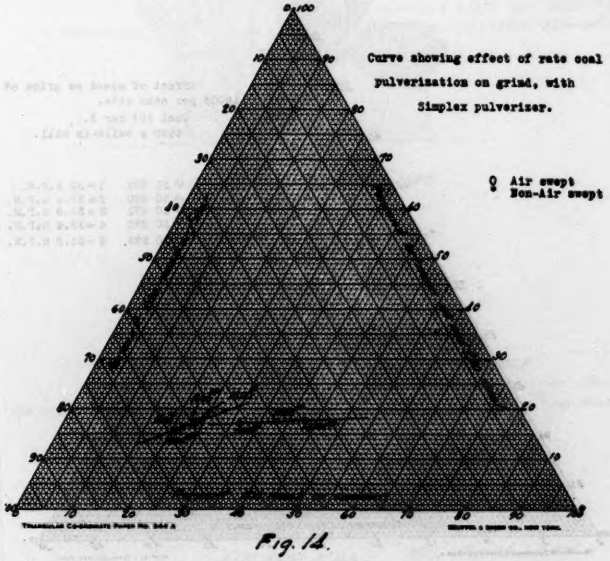


Fig. 14.

these details is the taking of the major portion of the air through the primary air fan without passing it through the mill — thus *not* air sweeping it violently, but merely allowing sufficient air to pass through the mill to insure steady coal flotation to the primary air fan.

The methods of taking primary air with the second and third types of pulverizer used are shown in Figure 16.

In the case of the second type of mill used primary air could be taken into the system by two methods: first, through an air open-

ing below the feeder and rotary magnetic separator as shown in (A) of Figure 16; second, through the outboard end of the primary air fan as shown in (B) of Figure 16. Use of the first method causes the mill to be air swept making for coarse product from the mill with consequent difficulties in distribution and combustion; use of the second method, taking barely enough air through the opposite end to allow even flow of coal to the primary air fan leads to finer grind and lessened difficulties from distribution and slow combustion.

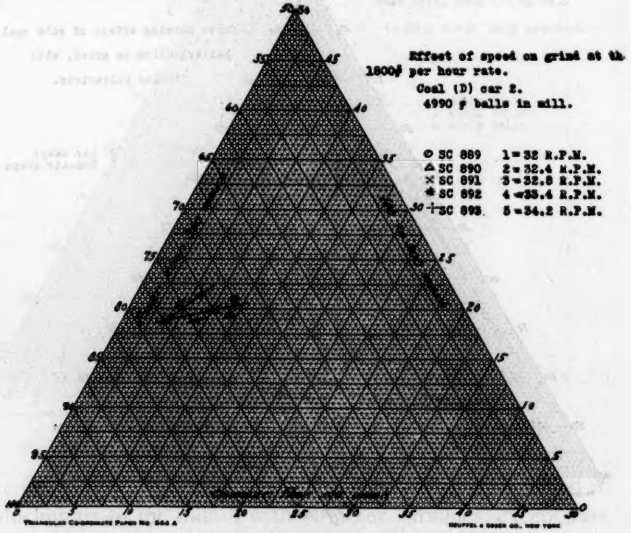
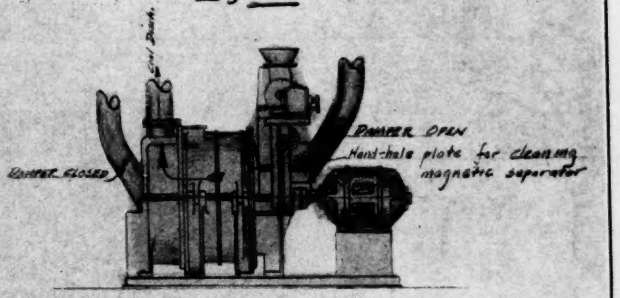

Effect of speed on grind at th
1800# per hour rate.
Coal (D) car 2.
4990 # balls in mill.
SC 889 1=32 R.P.M.
SC 890 2=32.4 R.P.M.
SC 891 3=32.8 R.P.M.
SC 892 4=33.4 R.P.M.
SC 893 5=34.2 R.P.M.

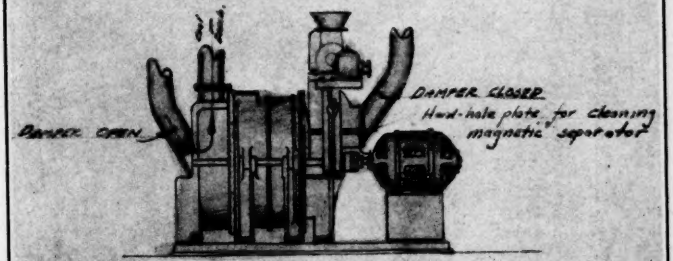
Fig. 15

With the third type of pulverizer primary air could be introduced into the system by four different methods, because of the duplex fan used and the air admission area provided between the mill and the fan. These methods are illustrated in Figure 16. Sketch (C) shows setting for using only that end of the fan toward the mill taking all air through the mill. This procedure causes air sweeping of the mill tending to cause coarseness of

Fig. 16.



SIMPLEX MILL - AIR SWEPT
Fig. A



SIMPLEX MILL - NON AIR-SWEPT
Fig. B.

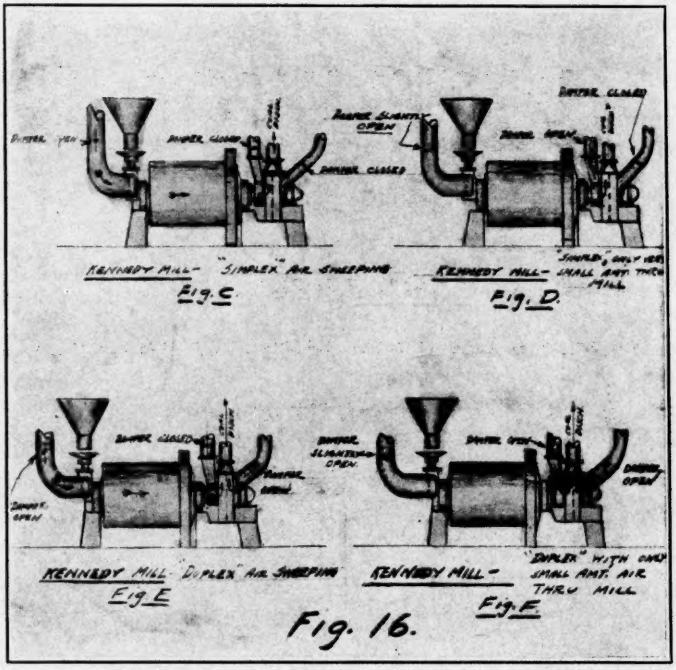

KENNEDY MILL - "SIMPLEX" AIR SWEEPING
Fig. C
KENNEDY MILL - "SIMPLEX" WITH ONLY SMALL AMT. AIR THRU MILL
Fig. D
KENNEDY MILL - "DUPLEX" AIR SWEEPING
Fig. E
KENNEDY MILL - "DUPLEX" WITH ONLY SMALL AMT. AIR THRU MILL
Fig. F

Fig. 16.

product, with ensuing difficulties. Sketch (D) shows setting for using only that end of the fan toward the mill but taking only enough air through the mill to insure steady flow of coal to the fan — the major portion of the air being taken through the duct between the mill and the fan. Sketch (E) shows setting for using both ends of the fan taking a large portion of air through the mill and the remainder through the outboard end of the fan. This procedure causes partial air sweeping of the mill causing the product to be somewhat coarse. Sketch (F) shows setting for using both ends of the fan taking a large portion of the air through the duct between the mill and the fan, nearly all the remainder through the outboard side of the fan, and taking only sufficient air through the mill proper to insure steady delivery of coal to the fan.

Methods illustrated in sketches (C) and (E) cause air sweeping of the mill with attendant coarseness of grind. These methods of air introduction should not be used unless very wet coal is encountered. Passing the major portion of the air through the mill is permissible in that exigency only — the hot air to the mill proper then being advantageous because of its drying action. Methods illustrated in sketches (D) and (F) are practically similar to each other as far as their affect upon the fineness of product is concerned, but different as to distribution.

When using the method of sketch (D) all the primary air and coal were delivered to the distributor from one end of the fan and equal coal and air feeding across the bottom of the distributor was impossible particularly with a length of travel of about one foot between the fan outlet and the base of the distributor. When using the method of sketch (F) a very rich mixture of air and coal is delivered from the end of the fan nearest the mill; the air delivered from the opposite side, but carrying no coal was supposed to mix with the coal carrying air and form a diluted mixture before the distributor. Quite the reverse occurred, however, a blast of coal, being fed to one side of the base of distributor and a stream of air to the other. It will be readily seen that the method of sketch (D) was the better of the two and was used throughout all runs made after the second week of July 1927, the duct to the outboard end of the primary air fan being blank flanged.

During the operation with the impact or hammer mill little difficulty was experienced with distribution; although it was not perfect, the differences in the amount of coal per furnace were relatively slight. This was due to the fact that a comparatively good mixture of air and coal was obtained before the distributor, and the latter could accomplish fairly equal distribution to the three furnaces. As previously described, however, the third type of mill used was furnished with a divided fan and primary air could be taken by any of the methods which have been considered.

When using any of these methods the mixture of coal and air at the base of the distributor was unequal; thus in order to secure good distribution with this installation it was necessary for the distributing device to be a very efficient mixer as well as a distributor.

The original device used, which was designed and furnished by the Peabody Engineering Corporation, is shown as (A) in Figure 17, was a good one if a uniform mixture of air and coal were furnished at its base, but as this was non-uniform in the case of the third pulverizer, the distribution of coal to the three furnaces was very unequal. Consequently this distributor — which had been used throughout the runs with the second installation (impact pulverizer) was removed after it had been used on several runs with the third, and the device shown as (B) in Figure 17 erected in its stead. This modification was designed by Lieutenant-Commander Kirtland of the Fuel Oil Testing Plant.

Runs with this distributor showed great improvement over the distribution previously obtained, although the amounts of coal per furnace were not exactly equal at certain rates. It was agreed, however, that study of the problem of distribution would be continued after a long run had been made to more adequately determine the suitability of the entire installation for marine service.

In view of the very complete data which had been gained on this installation, leaving the problem of distribution for further consideration, it was agreed — during the second week of July 1927 — that the set-up was in readiness for a ten-day simulative Transatlantic Run.

It was decided that this run was to have a total duration of 240 hours. The coal firing rate was to be changed after each 48 hours continuous operation, five rates to be run consecutively,

viz.: 1200, 1400, 1600, 1800 and 2000 pounds coal per hour per boiler. The personnel of the Fuel Oil Testing Plant was divided into three equal parts each making up an eight-hour watch, the engineers of the Shipping Board who were present and the representatives of the burner and mill manufacturers being also assigned to this duty. Lieutenant-Commander F. D. Kirtland, U. S. N., of the Plant, was in charge of one of these watches, the remaining two being headed by the authors of this article.

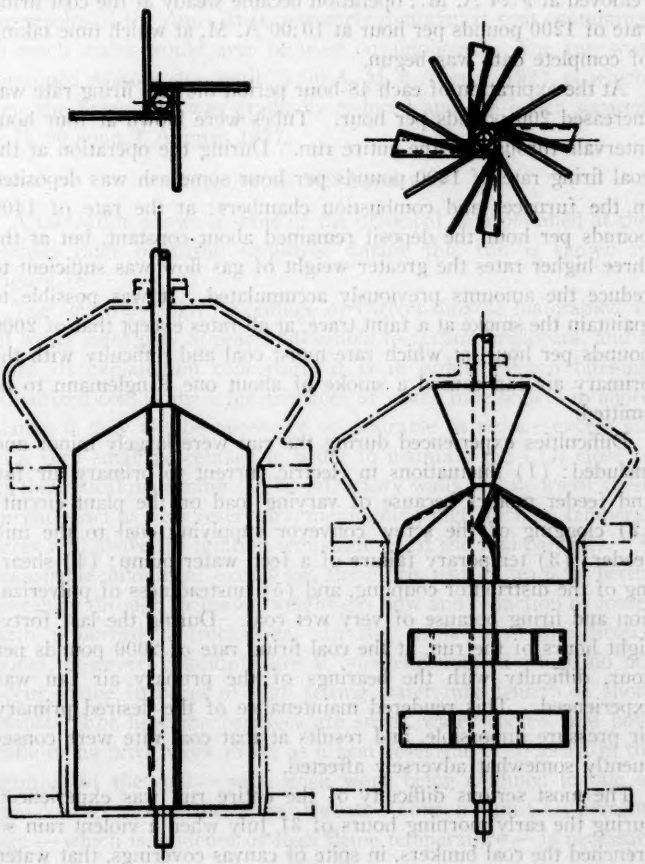


FIG. 17.

Immediately prior to making this run the fire and water sides of the boiler were thoroughly cleaned and inspected. A hydrostatic test showed the boiler to be without leaks.

Steam was brought to 180 pounds per square inch gauge, burning fuel oil during the afternoon of 26 July, 1927. The following morning, 27 July, the boiler was lighted off with fuel oil at 8:00 A. M. and after testing safety valves, burners were shifted from oil to coal at 9:12 A. M. Fuel oil was secured and atomizers removed at 9:24 A. M.; operation became steady at the coal firing rate of 1200 pounds per hour at 10:00 A. M. at which time taking of complete data was begun.

At the expiration of each 48-hour period the coal firing rate was increased 200 pounds per hour. Tubes were blown at four hour intervals throughout the entire run. During the operation at the coal firing rate of 1200 pounds per hour some ash was deposited in the furnaces and combustion chambers; at the rate of 1400 pounds per hour the deposit remained about constant, but at the three higher rates the greater weight of gas flow was sufficient to reduce the amounts previously accumulated. It was possible to maintain the smoke at a faint trace, at all rates except that of 2000 pounds per hour, at which rate moist coal and difficulty with the primary air fan caused a smoke of about one Ringlemann to be emitted.

Difficulties experienced during the run were largely minor and included: (1) fluctuations in electric current to primary air fan and feeder motors because of varying load on the plant circuit; (2) clogging of the screw conveyor supplying coal to the mill feeder; (3) temporary failure of a feed water pump; (4) shearing of the distributor coupling, and (5) unsteadiness of pulverization and firing because of very wet coal. During the last forty-eight hours of the run, at the coal firing rate of 2000 pounds per hour, difficulty with the bearings of the primary air fan was experienced. This rendered maintenance of the desired primary air pressure impossible, and results at that coal rate were consequently somewhat adversely affected.

The most serious difficulty of the entire run was experienced during the early morning hours of 31 July when a violent rain so drenched the coal bunkers, in spite of canvas coverings, that water

ran from the weighing bin and actually dripped from the feeder disc. An analysis of the coal used during this watch showed 18 per cent moisture. By diverting the primary air to sweep the mill with preheated air, the mill continued to pulverize, but its capacity was so greatly diminished by the presence of coal slush that the streams of pulverized coal to the burners became so lean that it was twice necessary to relight the coal with the fuel oil burners. The time consumed while thus being forced to relight the coal was so brief, however, that it may be neglected in consideration of the results of the run. It is extremely doubtful if coal containing so much water would ever be used on shipboard. The run was continued without stop until 10:00 A. M. 6 August, 1927, at which time the firing rate was gradually reduced and the boiler secured at 12:00 noon, 6 August, 1927.

RESULTS OF 240-HOUR RUN.

A tabulation showing some of the principal data obtained at the various rates of firing employed during this run is shown in Figure 18.

The relatively high percentage of carbon dioxide maintained at all firing rates may appear undesirable to certain engineers, and a word of explanation concerning it is in order. When burning pulverized coal in the large furnaces of water tube boilers in shore plants, it may not be necessary or desirable to reduce excess air to a very small percentage in order to maintain the CO_2 close to its theoretical maximum. The refractory walls and floors of these furnaces act as heat reservoirs, maintaining high furnace temperatures well above the ignition temperatures of the coal particles. A reasonable amount of excess air, therefore, usually leads to better efficiency through increased weight gas flow and reduction of losses with unburned hydrocarbons. In the furnaces of the Scotch boiler, however, conditions are at once encountered which do not occur in the furnaces of high setting water tube boilers of shore plants. For here the furnaces are small, water cooled, and have little or no brick work to act as a heat reservoir or to assist in the ignition of the coal — such brick work being confined to one or two courses around the burner throat. Thus, a high CO_2 percentage — which is evidence of high flame temperature — is necessary

in this boiler to preclude loss from chilling of carbon particles before combustion is complete. Furthermore, it is not to be overlooked that the entire area of the furnaces of the Scotch boiler is water heating surface, a large portion of the heat absorbed being radiation from the flames themselves. As radiant heat varies as the fourth power of the temperature (Stefan-Boltzmann's law) a high furnace temperature — evidenced by high CO_2 — leads to increased efficiency.

The heat liberated per cubic foot of furnace volume per hour during the 240-hour run also merits consideration. Based on the total volume of furnaces and combustion chambers, after subtraction of the space occupied by the brickwork around the furnace throat, or 469.98 cubic feet, these figures were: at the 1200 pounds per hour rate 37,087 B. T. U. per cubic foot per hour; at 1400 pounds per hour rate 42,096 B. T. U. per cubic foot per hour; at 1600 pounds per hour rate 48,924 B. T. U. per cubic foot per hour; at 1800 pounds per hour rate 55,799 B. T. U. per cubic foot per hour; and at 2000 pounds per hour rate 60,036 B. T. U. per cubic foot per hour. The boiler horsepower and percentage of boiler rating ranged from 390 (156.1 per cent) at the 1200-pound rate of firing to over 590 (237 per cent) at the 2000-pound rate.

The greatest overall (boiler, furnace, and burners) efficiency — on coal *as fired* basis — was obtained at the 1400-pound rate when it was nearly 77.1 per cent; the lowest was at the 2000-pound rate, when it was 70.3 per cent. Much higher efficiencies than those shown by these averages were obtained during periods — sometimes of several hours duration — when the coal was quite dry and excellent distribution was obtained. Had it been possible to maintain distribution at a uniform excellence equal to that obtained for the best periods, the overall efficiencies would have been considerably higher than the averages obtained.

Curves showing the rate of coal supplied to the mill, actual evaporation, equivalent evaporation per pound of fuel, and calorimeter readings for the 48-hour period at the combustion rate of 1400 pounds per hour are shown in Figure 19 as an example of the steadiness of operation at all rates except during periods when the coal became very wet due to severe rain squalls.

ABRIDGED DATA SHEET SHOWING PERTINENT DATA

SHEET 1 of 2

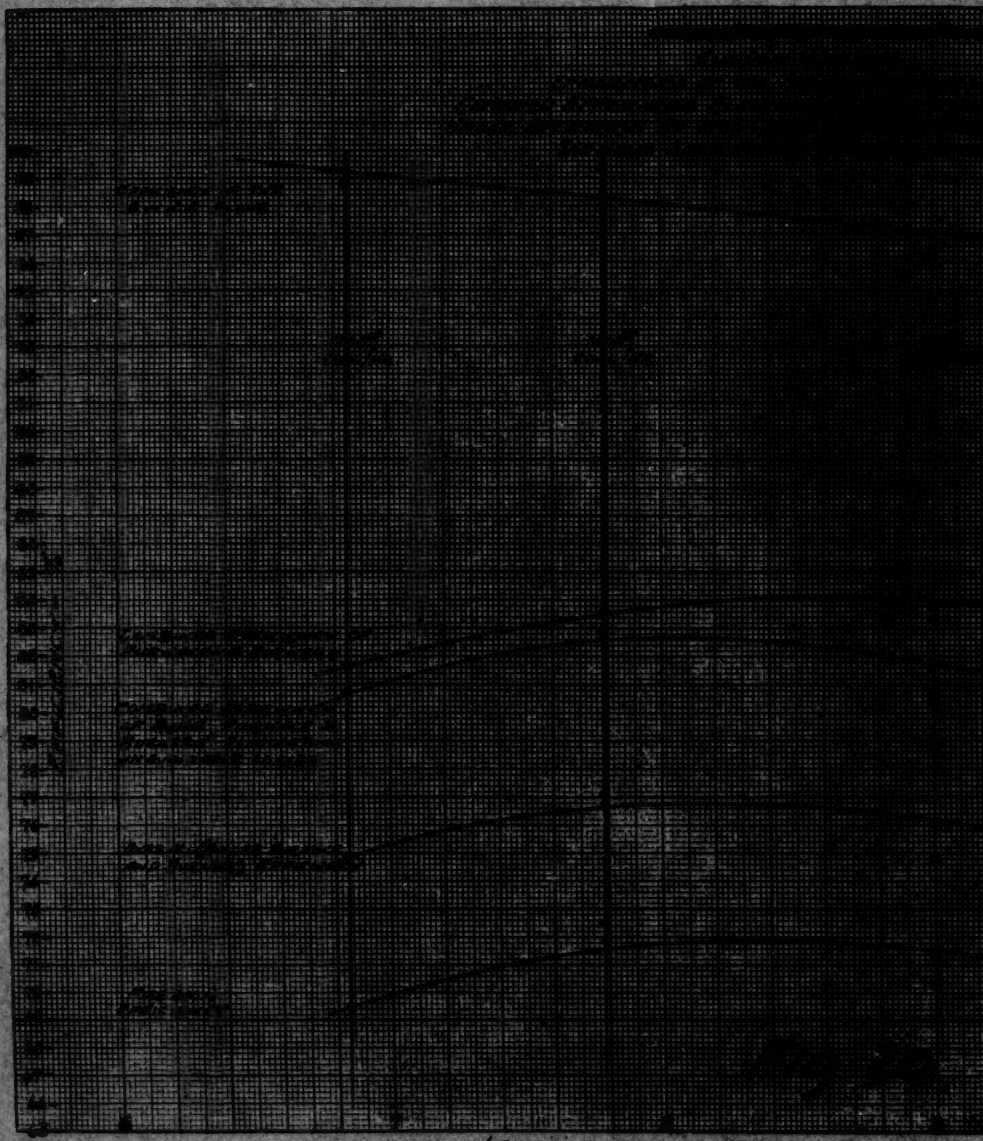
1	RUN NUMBER	80 (a)	80 (b)	80 (c)	80 (A)	80 (C)
3	BOILER WATER HEATING SURFACE - SQ. FT.	23653	23653	23653	23653	23653
4	ORIGINAL FURNACE VOLUME - CU. FT.	462.90	462.90	462.90	462.90	462.90
5	PRESENT FURN. VOL. CU. FT. & AFTER INSTALLATION OF BURNER BRICK WORK.	462.90	462.90	462.90	462.90	462.90
30	FUEL OIL TESTING PLANT NO. OF COAL SAMPLE	80 878	80 879	80 880	80 881	80 882
31	FIXED CARBON	72.1	71.0	71.7	72.5	72.9
32	VOLATILE MATTER	20.1	20.8	20.0	20.3	21.2
33	MOISTURE	2.1	2.6	2.5	2.4	2.8
34	ASH	5.7	6.0	5.7	5.0	4.0
35	TOTAL	100%	100%	100%	100%	100%
36	SULPHUR - SEPARATELY DETERMINED	1.1	1.7	1.6	1.5	1.6
37	CARBON (C)	81.2	80.7	81.4	82.2	80.6
38	HYDROGEN (H)	5.0	4.9	4.9	4.9	4.9
39	SULPHUR (S)	1.1	1.7	1.6	1.5	1.6
40	NITROGEN (N)	1.4	1.2	1.2	1.2	1.4
41	OXYGEN (O)	5.0	5.4	5.2	5.2	5.4
42	ASH	5.7	6.2	5.6	5.0	4.9
43	TOTAL	100%	100%	100%	100%	100%
44	CALORIFIC VALUE B.T.U.	14440	14305	14377	14545	14295
70	RETAINED ON #40 SIEVE					
71	RETAINED ON #50 SIEVE, PASSING #40 SIEVE	1.4	0.8	0.7	0.8	0.7
72	RETAINED ON #70 SIEVE, PASSING #50 SIEVE	2.5	1.4	2.2	2.2	2.2
73	RETAINED ON #100 SIEVE, PASSING #70 SIEVE	4.5	3.4	4.0	4.2	4.0
74	RETAINED ON #140 SIEVE, PASSING #100 SIEVE	4.2	4.7	4.8	4.4	5.1
75	RETAINED ON #200 SIEVE, PASSING #140 SIEVE	8.2	8.0	8.7	8.4	8.7
76	RETAINED ON #300 SIEVE, PASSING #200 SIEVE	9.5	10.5	9.3	10.3	9.6
77	PASSING #300 SIEVE	69.8	71.0	70.1	69.4	69.6
90	CARBON DIOXIDE % CO_2	16.2	16.7	17.0	17.1	16.3
91	OXYGEN % O_2	2.55	2.0	1.7	1.6	2.9
92	CARBON MONOXIDE % CO	.006	0	0.5	0.79	0.13
93	NITROGEN % N_2	81.148	81.3	80.8	80.51	80.77
98	SMOKE - RINGELMAN SCALE	1/4	1/4	1/4	1/2	1 to 2
110	STEAM PRESS. ON BOILER 135./80.* ABSOLUTE	136.7	136.8	136.8	137.1	136.1
116	DRAFT AT BASE OF SMOKE PIPE	-0.30	-0.35	-0.34	-0.33	-0.34
137	TEMP. SECONDARY AIR ENTERING BURNERS °F	316.3	316.7	316.1	316.3	331.8
139	TEMP. PRIMARY AIR ENTERING BURNERS °F	144.8	147.1	140.8	140.6	137.4
144	AV. TEMP. GASES LEAVING HEATER °F	416.1	418.0	394.8	391.6	388.7
145	AV. TEMP. GASES BEFORE HEATER °F	331.6	330.9	329.0	329.8	340.0
147	TEMP. STEAM CALORIMETER	306.7	306.7	306.9	307.3	307.7
148	TEMP.SAT. STEAM IN BOILER AT BOILER PRESS.	377.72	377.6	377.9	378.0	378.5

Fig. 18

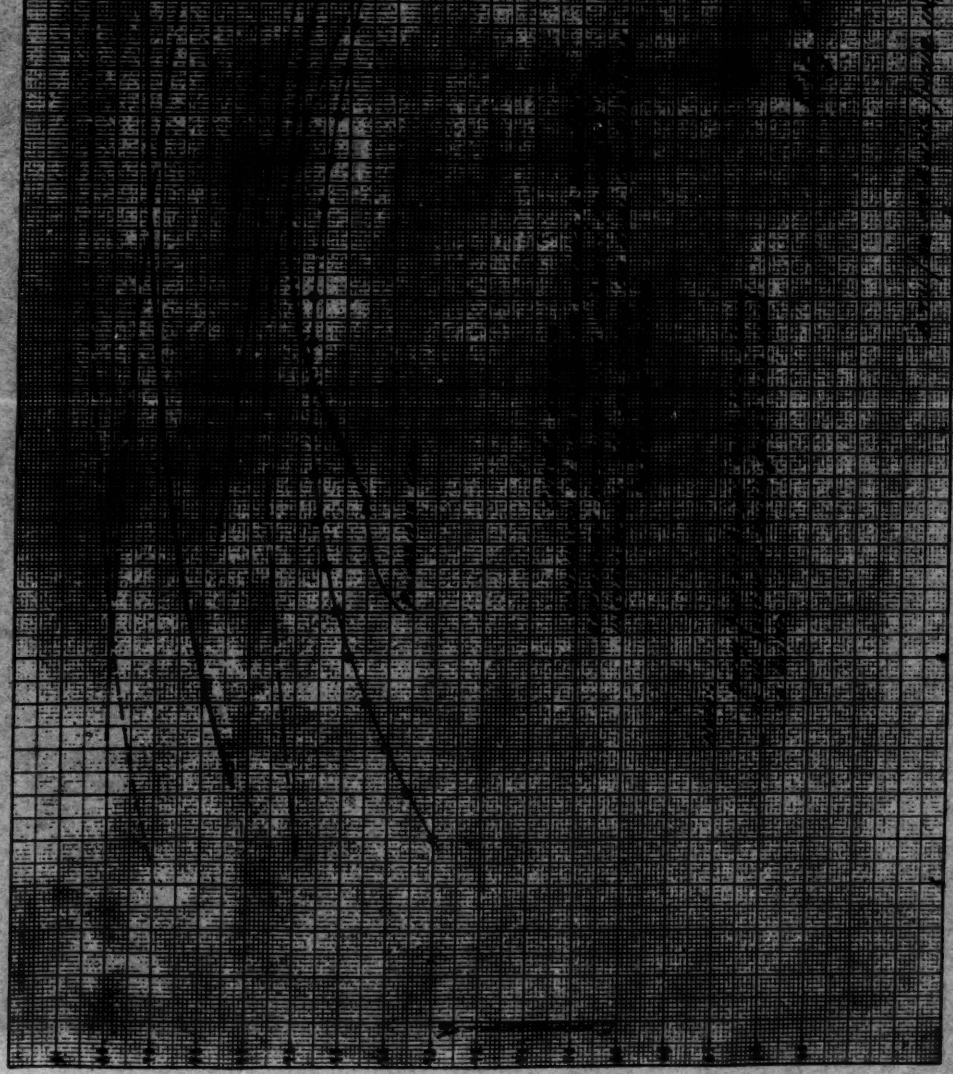
ARIBOER BOILER SHEET, SHOWING PERTINENT DATA

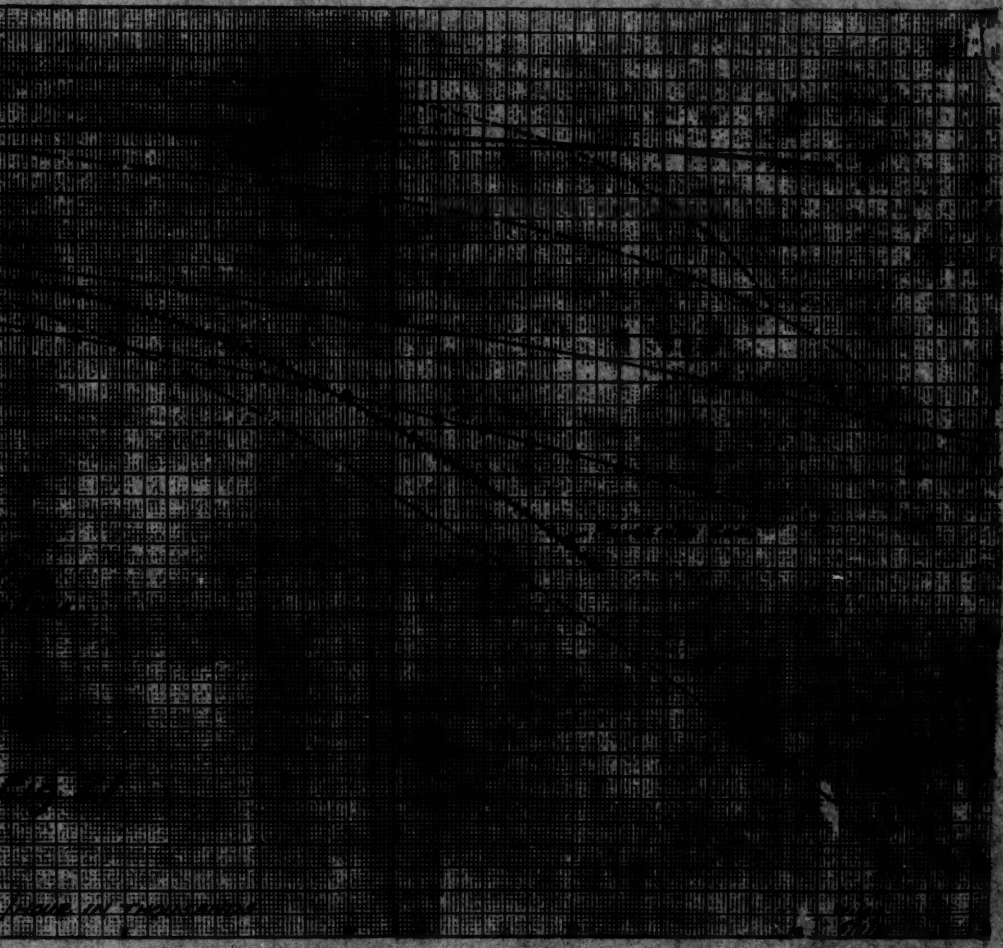
					SHEET No 2	
165	TEMP. OF FEED WATER ENTERING BOILER oF	202.4	208.0	219.2	208.6	210.4
169	FUEL SPEED - R.P.M.	88.4	88.4	88.4	88.4	88.4
171	EXHAUSTER SPEED - R.P.M.	1220.0	1220.0	1220.0	1195.0	1220.0
175	DURATION OF RUN - MINUTES	60	60	60	60	60
176	COAL FIRED - TOTAL FOR ALL MILLS	87000	84000	78750	84450	84000
177	ACTUAL TOTAL EVAP. OF B.T.U.S. 165.	615000	710000	831244	804000	828748
178	COAL FIRED PER HOUR - 165.	1305.4	1260.0	1260.0	1260.0	1278.0
180	COAL FIRED PER SQ. FT. B.T.U.S. PER HOUR - 126.	.47	0.46	0.46	0.460	0.47
184	COAL FIRED PER FURNACE PER HOUR - 126. ASSUMING EQUAL DISTRIBUTION	435.0	441.1	880.1	600.14	859.4
185	COAL FIRED PER CU. FT. OF FURNACE VOL. PER HR.	0.548	0.534	0.405	0.69	0.502
187	B.T.U. FIRED PER HR. PER SQ. FT. B.T.U.S.	6651.9	7745.6	8992.8	10264.C	11068.8
189	B.T.U. FIRED PER HR. PER CU. FT. OF FURN. VOL.	87084.8	45854.8	48888.7	58750.6	58058.8
190	ACTUAL EVAPORATION OF B.T.U.S. PER HR. - 165.	12819.06	14774.6	16501.0	16681.30	17265.0
200	QUALITY OF STEAM - %	98.81	98.81	98.81	98.88	98.84
201	ACTUAL EVAPORATION PER HR. CORRECTED FOR MOISTURE	12796.7	14860.3	16460.9	16588.8	17248.8
202	FACTOR OF EVAPORATION	1.0252	1.0215	1.0208	1.0201	1.0201
203	EQUIVALENT EVAPORATION OF B.T.U.S. PER HR. - 165.	13440.0	15717.9	17718.7	17007.6	18438.9
204	ECONY. EVAP. PER SQ.FT. B.T.U.S. PER HR.-165.	8.27	9.18	9.98	7.78	8.88
205	ECONY. EVAP. PER LB. OF COAL AS FIRED - 165.	11.166	11.54	11.077	11.05	10.348
206	BOILER HORSE POWER - NET	870.1	488.8	818.8	874.8	888.4
207	EFFICIENCY RATING %	166.7	178.8	201.0	200.4	201.0
211	ECONY. GUAGE PER HR. PER DRIVING PISTON	7.0	8.95	6.58	8.8	8.76
213	ECONY. STEAM PER HR. PER DRIVING PISTONHORSE	14.8	14.10	13.88	14.0	9.84
217	ECONY. STEAM PER HR. PER DRIVING PRIMARY AIR FAN	99.8	10.68	110.8	106.7	127.8
218	ECONY. STEAM PER HR. PER DRIVING EXHUSTER STEAM AND MILL	866.0	866.0	866.0	866.0	866.0
219	ECONY. STEAM PER HR. PER DRIVING SECOND. AIR FAN	88.6	88.7	84.2	100.4	106.1
220	ECONY. STEAM PER HOUR PER DRIVING FEED PUMP	350.0	376.4	488.8	478.0	467.4
240	% HEATED AIR OVER THEORETICAL AMT. REQUIRED FOR COMPLETE COMBUSTION.	18.88	9.88	8.86	8.877	10.67
242	STAT. EFFICIENCY-HEAT ABSORB.-HEATING SURFACE BASED ON	1054.9	1008.4	994.4	1007.1	1008.6
243	HEAT LOSS CHARGEABLE TO B.T.U.S. AND FURNACE - BTU.	2070.8	2782.7	2887.6	2871.6	2866.0
272	HEAT LOSS CHARGEABLE TO FURNACE & FURNACE - BTU.	2466.0	2860.7	2856.0	2887.0	2688.9
273	HEAT LOSS CHARGEABLE TO B.T.U.S. - BTU.	616.8	861.4	891.0	786.6	860.2
275	HEAT ABSORBED BY BOILER PER LB. COAL B.T.U.	10888.8	11888.96	10748.1	10788.9	10867.7
277	OVERALL EFFICIENCY OF B.T.U.S., FURNACE, AIR HEATER AND ECONOMIZER - %	76.88	77.60	76.97	76.88	76.88
278	EFFICIENCY OF B.T.U.S. %	88.88	89.87	86.66	76.88	86.87
279	COMBINED EFFICIENCIES OF FURNACE AND BURNERS	81.88	86.86	88.88	86.81	88.76
280	COMBINED EFFICIENCIES OF B.T.U.S., FURNACE, AIR HEATER, AND ECONOMIZER, NEGLECTING RADIATION LOSSES %	86.7	82.86	86.88	76.66	76.88
282	GASES RECOVERED BY AIR HEATER %	6.86	8.18	6.88	8.81	8.48
288	FURNACE EFFICIENCY USING B.O.T.U. BOUGHT	88.87	72.6	76.88	88.88	88.88

Fig. 18


B.T.U./SQ.FT. B.W.H.S./HOUR IN THOUSAN

OUSANDS.





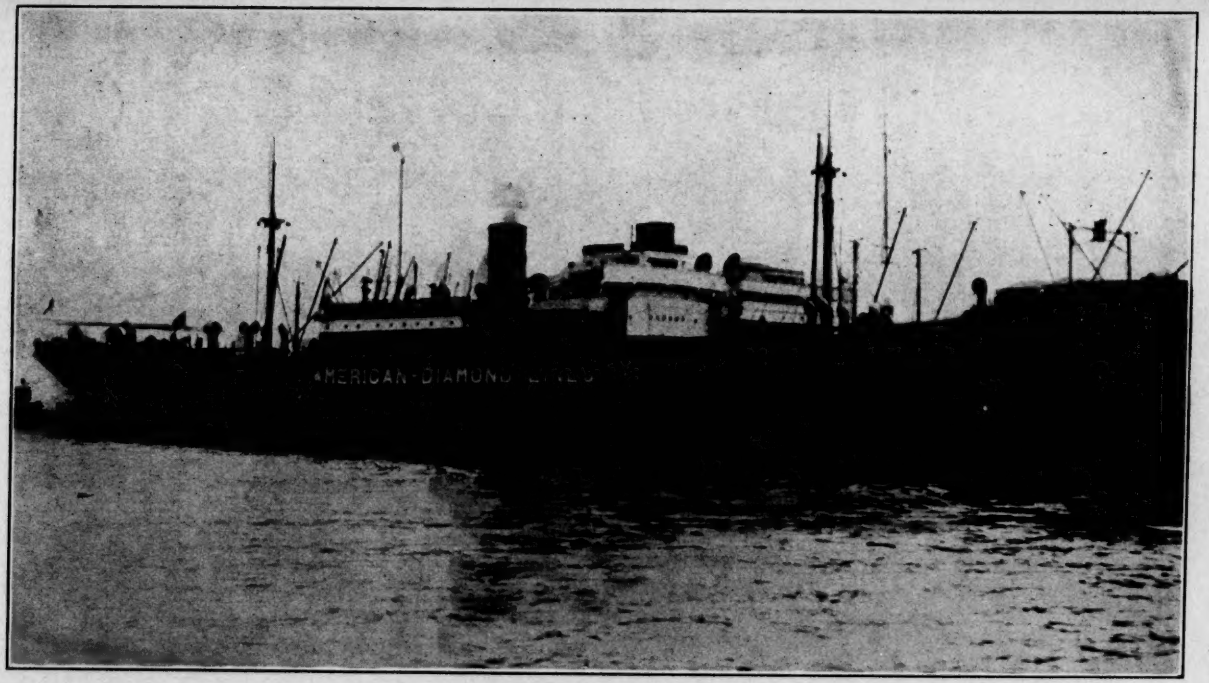


FIG. 22.

Figure 20 shows efficiency curves obtained from this run. The average overall (boiler, furnaces, and burners) efficiency obtained for the range of rates run was 74.14 per cent; the average fireroom efficiency (after deduction of all steam to auxiliaries, except of feed water pump) was approximately 69.6 per cent; the average steam used by the fireroom auxiliaries, including feeder, pulverizer, distributor, primary and secondary air fans, was therefore approximately four and one-half per cent.

A comparison of the overall (boiler, furnaces, and burners) efficiency obtained with this pulverized coal installation versus similar efficiencies obtained with fuel oil burners previously tested on the same boiler — but before it was equipped with air heater and double front — is afforded by Figure 21. After consideration of the differences in these efficiencies, a rough estimate of the cost of the coal required to furnish a given number of B. T. U.'s versus the cost of oil for a like number of B. T. U.'s will show a large saving in favor of the pulverized coal.

The Fuel Conservation Committee having made a careful study of the results obtained on the ten-day simulative service test, decided that the success obtained warranted continuing the experiment on a sea-going vessel. They so recommended to the Shipping Board, requesting that the S. S. *Mercer* be assigned for the test. This request was complied with.

The *Mercer* — shown in Figure 22 — is a 9500-ton cargo vessel built by the Federal Shipbuilding Co., at Kearney, N. J., in 1920. It is equipped with a 2500-horsepower General Electric geared turbine, three single ended three furnace Scotch boilers, and the usual auxiliaries found on an oil burning vessel of this class. The boilers are but slightly larger than the one used in the tests at the Fuel Oil Testing Plant, and similar to it, have a separate combustion chamber for each furnace.

This vessel, which at the time of selection for conversion was one of the laid up fleet, was chosen because a number of her sister ships were in operation, some with oil burners, while others were hand-fired coal burners. The addition of the *Mercer*, as a pulverized coal burner, to the active fleet would result in data becoming available from similar vessels in the same service but using

three different fuels. One other fact which led to the selection of the *Mercer* was that it was equipped for burning fuel oil, and, with Peabody Pulverized Coal burners a change from coal to oil could be made in a few minutes if, for any reason, the burning of pulverized coal was found to be infeasible.

Necessary plans for conversion of the vessel were made by the Shipping Board, and all such plans as referred to the pulverized coal installation were submitted to the Fuel Oil Testing Plant for comment or criticism. Plans and specifications for the necessary work having been satisfactorily completed, bids for doing the work were requested from various ship repair yards. The contract was given to the Maryland Dry Dock Co., of Baltimore, Md.

The work to be done included the conversion of certain spaces into coal bunkers and the installation of coaling hatches, as well as the installation of the entire pulverized coal burning apparatus. The bunkers were so arranged that, in as far as possible, all coal fed by gravity to the level of the deck of the pulverizer room. Here the coal fed through a heavy four-inch mesh screen, the larger lumps of the run of mine coal being broken by hand, to the trough of an endless-chain bucket conveyor. This delivered the coal to the crusher which was located two decks above the pulverizer. The crusher reduced the coal so that no pieces were larger than 1½ inches in greatest dimension and delivered the product to a ready bunker directly underneath the crusher. From here it fed by gravity to the pulverizer feeder which was directly beneath. The capacity of the ready bunkers was such that they needed to be filled but onec or twice a day, and the conveyors and crushers were run only when such ready bunkers needed filling.

The crushers were the Jeffrey single roll type driven by Sturtevant engines, which also, by means of suitable clutches, drove the endless Link-Belt Conveyors mentioned above.

The two pulverizers were the previously described Kennedy-Van Saun ball mills, but were engine driven instead of turbine driven. These engines were duplicates of those used on the crushers. The feeders of the pulverizers were not the same as were used at the Fuel Oil Testing Plant, the design having been modi-

fied so that the coal was supplied from the ready bunkers, through the feeders to the mills by closed systems.

The primary air fans were built by the Kennedy-Van Saun Manufacturing and Engineering Corporation and were driven by Sturtevant turbines.

The installation of crushers, conveyors, pulverizers and primary air fans was in duplicate, there being a similar outfit on starboard and port sides.

The distributors were built by the Peabody Engineering Corporation and were driven by Coppus turbines. The burners were, of course, furnished by the Peabody Engineering Corporation.

All necessary piping was supplied by the repair yard, the coal piping being heavy steel while the air piping was of lighter material.

The work of conversion having been completed under the supervision of representatives of the Shipping Board, and coal having been taken on board tests were begun. It was early apparent that the primary air fans would have to be changed; the manufacturer had furnished duplex fans in spite of the difficulties experienced with this type of fan at the Fuel Oil Testing Plant. New simplex rotors were, therefore, built and installed and the air piping changed so as to be capable of operation in the same manner as previously described for the ten-day test run at the Plant.

Some trouble, which necessitated re-designing of certain parts, was also experienced wtih the distributors. Finally after all these minor troubles had been practically eliminated the real tests were begun.

On account of the difficulty of ascertaining the velocity in the pulverized coal lines which would be necessary to keep the coal from settling out of its carrier air — and thus plugging the feeder lines — all such data taken at the Plant was obtained on the basis of air pressure or drops in pressure between various points.

The sizes, lengths and arrangement of the pulverized coal piping used on the *Mercer* differed from that of the Plant installation, making such data as had been obtained at the Plant concerning air pressures of no value, and new data had to be obtained. In an endeavor to ascertain the lowest air pressure which could be maintained at the outlet of the primary air fan and yet have sufficient

velocity in the feeder lines to keep the coal from settling, the speed of the primary air fan was gradually reduced. This method of obtaining data by repeated trials was not without its difficulties as on several occasions the speed of the fan was allowed to drop too much, with the result that several lines plugged solid with coal. The only way in which they could be freed was by removing them and pounding the coal out onto the fireroom floor plates, from which it was gathered and restored to the pulverizer. However, the lowest permissible air delivery pressure at the fan outlet was finally established and since then no plugging of pipes has occurred from this cause.

The pulverized coal piping on the vessel was originally arranged as follows: the discharge lines from the starboard and port mills (primary fans) extended up and across the forward bulkhead of the boiler room to the center of the ship, where, at a place considerably above the height of the boilers, they were connected to the main distributor. A specially designed valve was installed in each line just before this distributor, so that, if only one mill was in operation there would be no danger of filling the other line and mill as long as the valve in the line from that other mill was closed. From this main distributor, discharge lines, each fitted with a valve at the main distributor end, led downward — one to each of three secondary distributors — one before each boiler. From each secondary distributor led three discharge lines — each fitted with a valve at the distributor end — one to each furnace of the boiler served by that distributor. The piping was so arranged that, with the exception of the main lines from the primary air fans to the main distributor, the flow of pulverized coal was always downward and all horizontal leads were avoided.

The early tests on the vessel during which one mill was used to furnish fuel for one boiler gave so much promise of success, in spite of only fair distribution, that it was decided to try one mill feeding two adjacent boilers. This was also accomplished with fair success, and distribution was about the same as when one boiler was used. Although this required somewhat greater air pressure at the outlet of the primary air fan than had been anticipated, it was decided to try to furnish fuel to all three boilers from one mill for the purpose of securing additional information. This

attempt ended in several hours of work of digging out coal from plugged feeder lines; it was apparent that not only were the primary air fans not of sufficient capacity for such a use but also that distribution was poor under these conditions.

No attempt was made to furnish coal from both mills at the same time to the main distributor as it was impossible to hold the same speed on the two primary air fans, and unless these were constantly in parallel there would be danger of flooding one fan with the discharge from the other, plus additional possibility of plugged lines.

At this time the pulverized coal piping was so changed that the starboard mill fed only the starboard boiler through the starboard auxiliary distributor, and the port mill fed only the port boiler through its auxiliary distributor. The equipment for the center boiler was left in place up to and including its distributor, it being decided that, for the present, oil only would be used on the center boiler if and when necessary. The piping which had been removed to effect this change was, however, kept on board ready for installation at any time.

Dock trials were held in order to use the steam from the two boilers under test, and on 4 November, 1927, all tests having been completed, the vessel left the repair yard for New York.

It had not been expected to use pulverized coal during the maneuvering periods of the vessel, until the crew had become more familiar with the installation, but this was also tried with the result that the vessel was easily maneuvered from her berth and out into the stream without resorting to fuel oil and without lifting safety valves.

A satisfactory run to New York harbor was made and the vessel docked at Hoboken, N. J., under pulverized coal, a total of thirty-two bells being promptly answered in a docking time of sixty-two minutes. This was likewise accomplished without resorting to fuel oil, without lifting safety valves and with a maximum drop in boiler pressure of only fifteen pounds from that at which the safety valves would lift.

While at Hoboken the vessel was opened for two days for inspection of the equipment by interested parties. Two days were also spent in making two short runs from the dock out to the

region of the Ambrose light vessel and return, and during these trips a large number of authorized guests were on board and witnessed the operation of the equipment.

The *Mercer* then proceeded to Philadelphia to take on cargo, returned to Hoboken to complete loading and to be bunkered, and on the night of 23 November, 1927, left Hoboken for Rotterdam.

For the purpose of observing the operation of the equipment under sea-going conditions and for taking data to be considered in connection with additional installations, several representatives of the Fuel Conservation Committee, a representative of the mill manufacturer, one from the manufacturer of the distributors and burners, and one from the Fuel Oil Testing Plant made this first voyage.

Heavy weather, such as is frequently encountered in the North Atlantic during November and December, was experienced during the greater part of the voyage, the vessel rolling as much as 32 degrees and pitching from 6 degrees to 8 degrees. However, the equipment functioned as satisfactorily as could be expected of any new and previously untried (under these conditions) machinery, and although there were a number of comparatively minor troubles, none of them cast any doubt on the feasibility of burning pulverized coal at sea under Scotch marine boilers.

The difficulties encountered were remedied on board and consisted of making and installing new flexible couplings between the primary air fans and their driving turbines; installing a spare flexible coupling between the engine crank shaft and the driving pinion of the starboard mill; repairing and re-installing of a ball bearing on a distributor; cleaning of a mixture of coal dust and grease from the driving gears of the mills (this mixture had accumulated in the lower half of the gear covers due to coal having been accidentally spilled while clearing the feeder mechanism); clearing the mill feeders which blocked several times due either to excessive use of grease on the mechanism or to improper adjustment; regulating and setting the governors on the engines driving the pulverizers (these governors seemed to stay in adjustment for only very uncertain periods); and in clearing the internal screens at the discharge ends of the pulverizers (these screens would become blocked with wood fibre resulting from pieces of

wood entering the mill with the coal and being ground to fibre, or by pieces of paper, thereby preventing the exit of the pulverized coal and resulting in an overflow of the mill). Distribution was fair to good when the distributors were operating, but coal leakage along the distributor shafts into the bearings and into the upper bearing of the driving turbines of the distributors caused considerable trouble.

The amount of coal fed to each furnace (quality of distribution) was checked not only by noticing the appearance of the fires in each furnace but also by gas analyses and thermocouple readings at the top center of each furnace smoke box while holding constant the secondary air pressures and maintaining similar settings of all burner registers.

When it was necessary to make repairs on any of this equipment, the fuel was changed from coal to oil on the boiler affected, the pulverizing plant for that boiler was secured, and repairs proceeded with. Upon their completion the boiler was again fired with pulverized coal and the oil atomizers shut off and removed. At no time during the voyage was it necessary to entirely discontinue the use of pulverized coal, as either one or the other boiler was always burning coal, and the total number of hours that oil was used was but a very small percentage of the number of boiler hours of the entire voyage. All the criticism which had been made of attempting to use ball type mills on sea-going vessels was shown to be unfounded, as the mills functioned satisfactorily even during periods of heavy rolling and pitching. The voyage was made on only two boilers (the third boiler being dead) burning pulverized coal, no trouble was experienced in making all the steam necessary, and the burners worked without any trouble.

The outward bound voyage was completed satisfactorily, except for the difficulties mentioned, and the arrival of the *Mercer* at Rotterdam on 8 December, 1927, was evidently taken as a signal for the ship owners and builders of Great Britain and Europe to gather at that port for an inspection of the equipment of the vessel.

On arrival at Rotterdam, the ship's decks were somewhat dirtier than would be the usual condition and in this connection it is pertinent to invite attention to the fact that the smoke stack of the

vessel was about 20 feet shorter than the stacks of sister vessels. The stack extended upward to just about the height of the deck of the flying bridge, with the result that, with winds from ahead or slightly on either bow, the ash from the stack was caught and blown down on deck.

While in Rotterdam some of the furnaces were examined and cleaned of any accumulation of ash and slag. This was the first cleaning any furnaces had had since fires were first started with pulverized coal in Baltimore during October. Furnaces showed an accumulation of three to four inches of ash and slag which was removed from some of them; such accumulations were allowed to remain in the other furnaces, as it was desired to find out whether the accumulation would be more or less rapid in the furnaces which had not been cleaned as compared with those that had been cleaned.

After a few minor corrective measures had been taken during the stay of the vessel in port, the *Mercer* started on its return voyage. Again some heavy weather was encountered but, other than some troubles similar to those experienced on the outbound trip, a successful voyage was made.

On this return voyage some coal which had been taken on board at Rotterdam was used. No difficulty was experienced in the pulverization and burning of this coal. However, steam was not kept up as easily as it had been with the coal used on the outbound voyage. An analysis of this coal taken on board at Rotterdam showed it to contain 12,400 B. T. U.'s per pound with 14 per cent ash, as compared with the 14,200 B. T. U.'s per pound with 7 per cent ash of the coal used on the outbound trip — hence the difference in ease of steaming.

Upon the completion of the first round trip all furnaces were cleaned and it was found that the accumulation of deposits in the furnaces which had been cleaned in Rotterdam was about three inches in depth, while that in the furnaces which had not been previously cleaned was about eight inches. It was also found that the front connections of the center boiler (which had not been in use throughout the entire voyage) were clogged with ash which had deposited there by dropping from the uptake, as no dampers had been fitted to any boilers, and the uptake was common to all

boilers. Dampers were, therefore, installed in an endeavor to completely isolate this boiler.

The stack was now increased sixteen feet in height and distributors of new design were installed on the two boilers. The screens at the discharge ends of the mills, which had been inaccessible without stopping the mills, were altered to permit removal and cleaning in about two minutes without the necessity of stopping the mills.

After unloading cargo at Hoboken, unloading and loading cargo at Baltimore and Norfolk, bunkering at Norfolk, and completing cargo at Hoboken, the vessel started on its second voyage. This trip, over and back, was about as successful as the first except that greater trouble was experienced with the distributors, due to pulverized coal from the distributor getting into and damaging the bearings of the distributor turbines; and trouble with the distribtuors naturally caused poor distribution of coal to the furnaces with the result that certain furnaces had greater deposits than did others. It was also found that the dampers which had been installed were not tight and that again there was some deposit of ash in the front connections of the center boiler. The lengthening of the stack, however, had had the desired effect and the decks were now free of ash.

Upon the completion of this second voyage, new primary air fans of more suitable design were installed, the coal registers of the burners of the starboard boiler were changed from left hand to right hand admission in order to give more nearly equal lengths of coal piping from the distributor to the burners, and the distributors were modified by the installation of air sealed glands in order to prevent, if possible, any coal from leaking out of the distributors.

After calling at the ports of Philadelphia, Boston, and Hoboken, at which last named port loading was completed, the *Mercer* started on its third voyage. On this voyage oil was used in one furnace of the center boiler in an endeavor to keep any ash from settling into the front connections.

The third voyage was as successful, if not more so, than either of the earlier ones, but some trouble was again experienced with distributors and distribution, and also with the feeders of the

mills; these feeders occasionally jammed due to various lengths of wire, which had in some way gotten into the coal, wrapping themselves around the feeder shafts and stalling the motors. The slight use of the center boiler had kept it free of deposits of ash.

During the visit of the *Mercer* to Philadelphia after this third voyage new distributors of a type which had just been developed at the Fuel Oil Testing Plant were installed and at the time this article is being written it is expected that the *Mercer* will use such distributors on her fourth voyage.

No exact data as to costs have as yet been released, but it is expected that such data will be given out by the Fuel Conservation Section of the Shipping Board in the near future. Pulverized coal has gone to sea and done so very successfully, and the vessel has maintained its sailing schedule which was laid down by its operators, American Diamond Lines, before the first voyage. It is believed that even greater success would have resulted had it been feasible to keep the vessl in home waters and to have experimented somewhat more before putting it into active service, but the vessel had been promised to the operators for a certain date, and time did not permit further trials before the first voyage.

While the S. S. *Mercer* was being fitted out with the pulverized coal installation as described above, and the first trips were being made to obtain accurate data on her performance as a pulverized coal fired ship, the problem of equalizing distribution was again attacked at the Fuel Oil Testing Plant.

Nine new types of distributors were successively tried out. The method of test was to first install them in the Plant Air House and obtain data concerning the flow of air through them by observations of the travel of pieces of confetti, and then set them up for actual test with the installation, operating successively at the maximum and minimum rate. In those instances where the distributors seemed to promise good distribution they were operated over the entire range of rates ordinarily used, viz.: 1200 to 2000 pounds per hour by 200 pounds increments.

Sketches showing cross-sectional views of the distributors which were set up for test are shown in Figure 23, and were as follows:

(A) Peabody Spiral Flight — Peabody Engineering Corporation — (motor driven).

(B) Williams — Sturtevant Company — (stationary blade type).

(C) Williams (stationary) with lined "mushroom." Sketch shows lined "mushroom" only.

(D) Williams (stationary) with upper blades removed.

(E) Kennedy straight paddle inverted cone distributor — Kennedy-Van Saun Manufacturing and Engineering Co. — (turbine driven).

(F) Kennedy curved blade inverted cone distributor — Kennedy-Van Saun Manufacturing and Engineering Co. — (turbine driven).

(G) Kennedy curved blade inverted cone distributor with blades modified. (Turbine driven.)

(H) A second type of Kirtland Distributor also using the lined mushroom shown in sketch (C), and then with the lining of the mushroom removed.

(I) Two eight-bladed fans, idling in the primary air — fans turning in opposite directions.

The results obtained from runs made with these distributors demonstrated that none of them was equal to the Kirtland Distributor as used on the 240-hour run. The Kennedy curved blade inverted cone distributor, shown in Figure 23 sketch (F), accomplished only very mediocre distribution when revolving under its own power, but when allowed to idle in the primary air stream very good distribution, superior to that obtained with the Kirtland, was obtained at coal rates above 1600 pounds per hour. At twelve and fourteen hundred pounds per hour, however, the distribution was very poor, and no manner of modification or speed changes caused it to give better results at low rates.

Realizing that the problem of distribution was still far from a hard and fast solution, it was decided to discontinue further work upon distribution until the FOURTH pulverized coal installation was set up for test.

The Peabody burners and Kennedy-Van Saun pulverizer with their piping were removed from the Pulverized Coal House during November 1927.

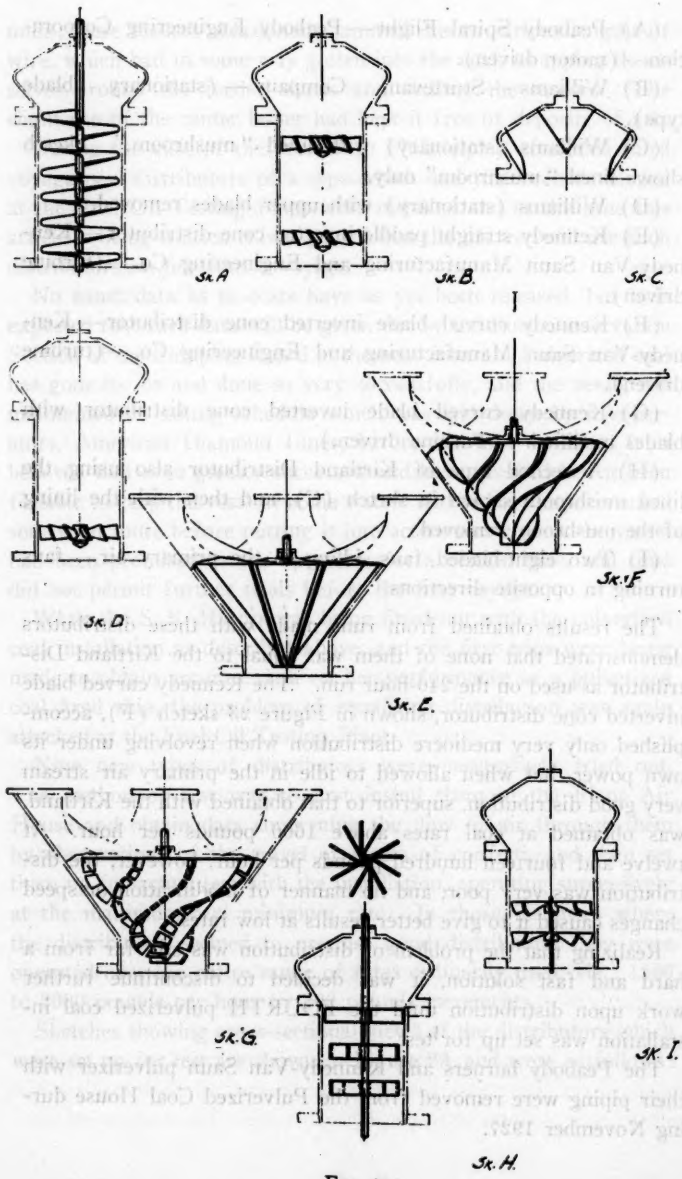


FIG. 23.

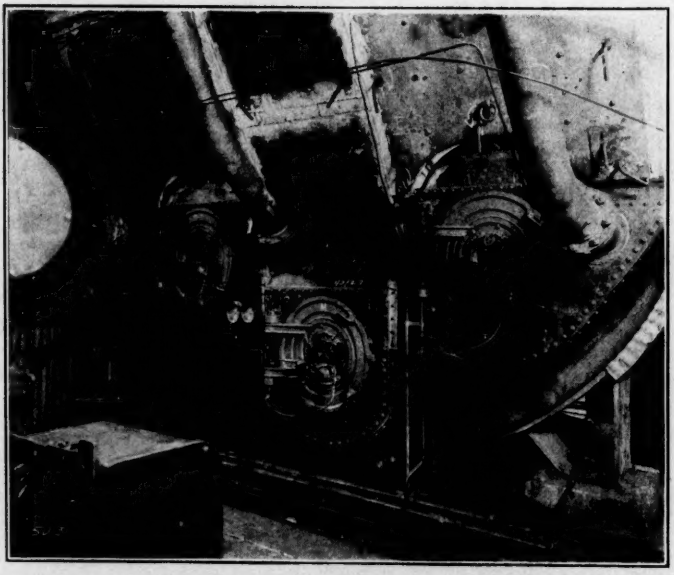


FIG. 24.

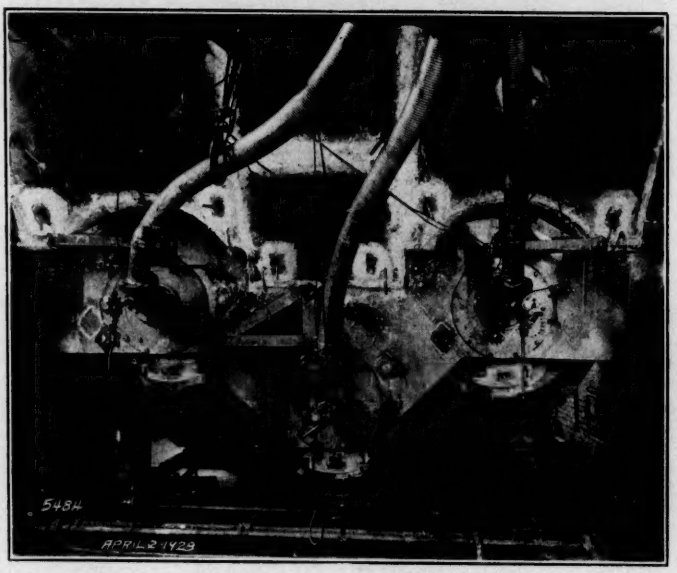


FIG. 25

Figure 24 shows the Peabody burners on the Scotch boiler immediately prior to being removed. In comparing this illustration with Figure 3 the greater simplicity of piping and the superior accessibility and ruggedness of these burners over those of the first installation, is immediately perceptible.

It will be recalled that the first pulverized coal installation set up at the Plant was withdrawn for further experimentation prior to erecting the second installation on the Scotch boiler. The manufacturers of the first burners, having completed tests of a new design of burner — though on a different type of boiler — indicated their desire to have the tests of their equipment continued as originally authorized.

Therefore, immediately after the removal of the third installation — consisting of the Peabody Pulverized Coal burners with the Kennedy-Van Saun mill — the work of setting up the FOURTH pulverized coal installation at the Fuel Oil Testing Plant was begun.

The Scotch boiler double front was altered to reduce the space between the boiler front proper and the exterior front to conform with the depth of the burner registers; segments of the furnace fronts below the registers themselves were not covered by the double front but were provided with clean out doors for the removal of ash from the furnaces. The double front, ash doors, register fronts, and piping to burners are shown in Figure 25. It will also be noted from this illustration that brackets were installed on the exterior of the double front — one above each burner. The purpose of these brackets is to support the burners when they are unbolted from the double front to allow access to the furnaces. The flexibility of the branch coal connections to the burners allows the burners to be pulled backward on their supporting brackets without disconnecting the coal piping.

Comparison of the methods of swinging out burners on the third installation with those of the fourth is afforded by study of Figures 24 and 25. It will be noted that it was not necessary to disconnect any piping in the case of the Peabody burners as the coal did not pass through the register front, which was hinged to permit opening, but passed into the coal register through the double front.

The burner of the FOURTH installation was a combined fuel oil and pulverized coal burner as was that of the third.

ATOMIZER.

A mechanical pressure atomizer passed through the center of the register, being ordinarily used for lighting off the coal, but may be operated with the register as a fuel oil burner. The atomizer can be readily withdrawn after use in lighting off coal; the quick detachable coupling at the fireroom end of the atomizer barrel allows it to be entirely removed or replaced at will.

COAL FIRING.

Pulverized coal is conveyed, by its carrier air via the feeder pipe as shown in Figure 25, to the central coal tuyere shown in Figure 26. The mixture of coal and air is blown against the impeller plate or diffuser beyond the end of the tuyere proper, rotation and turbulence being established by the passage of coal between the vanes of the impeller plate. An adjustable sleeve is mounted on the exit end of the tuyere proper; the setting of this sleeve controls the area of the impeller which is passed over by the pulverized coal stream, thereby influencing the shape and turbulence of the flame.

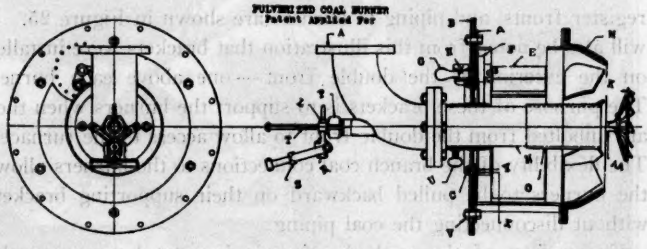


Fig. 26.

AIR REGISTER.

The air register is formed of two ring-shaped angle irons, the flange of one being toward the front, that of the other being against the circular cover plate. These two rings are separated

from each other by "T" pieces. Four quarter-inch shafts mounted between the ring flanges support four air doors. These doors form four segments of a circle, and when closed complete — with the "T" pieces — a cylinder, and practically exclude entry of air into the register. Adjustment of these doors is accomplished by a cam just inside the burner front plate; the cam is actuated by a lever manipulated from the outside of the register front. Notches are provided for maintaining the lever adjustment. The register also includes a cast iron bladed cone which constitutes the throat of the register. It is provided with eight blades set at 45 degrees intervals, each forming an angle of 30 degrees to the right from the horizontal center line of the cone.

PULVERIZER.

The pulverizer used in this series of test runs was the same type as that employed in connection with the first test, except of slightly larger size. Figure 27 shows side elevation partly in section together with a rear elevation of this mill.

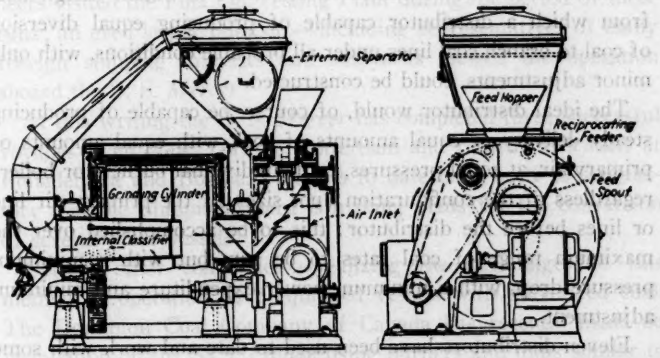


Fig. 27

This pulverizer is a ball mill, accomplishing coal reduction by impact and attritive action of metallic balls. It is to be noted that this pulverizer is equipped with an external separator, which is the structure above the mill proper. This upper classifier permits

separation of the coarser particles of coal from the finer — the former returning to the mill for further grinding, the latter passing into the piping system to the burners.

FEEDER.

The feeder consists of an adjustable crank-actuated rectangular trough feeding from both ends at periodic intervals.

PRIMARY AIR FAN.

The primary air fan was of the Sturtevant "Monogram" type manufactured especially for this type of installation. This fan was set up on a platform directly above the pulverizer, drawing pulverized coal and primary air from the mill through the classifier and discharging it through piping to a distributor from which the coal passed by way of a trifurcated connection into the three flexible branch lines to the burners.

At the beginning of the runs with this FOURTH pulverized coal installation, it was agreed that tests on various types of distributors should be continued in an effort to obtain design data from which a distributor capable of producing equal diversion of coal to branch coal lines under all probable conditions, with only minor adjustments, could be constructed.

The ideal distributor would, of course, be capable of producing steady delivery of equal amounts of coal, with equal amounts of primary air, at equal pressures, to the individual burners or boilers regardless of the configuration (not size) of the primary air line or lines before the distributor; this to be accomplished over the maximum range of coal rates to be run, but with a minimum pressure drop, with a minimum power expenditure and minimum adjustment.

Eleven distributors have been used to date and work with some of them is still in progress. These eleven distributing devices were as follows:

(A) Eccentric orifice plate.
(B) Line configuration alone.
(C) Skeleton paddle.
(D) Eccentric orifice plate with paddle.

(E) Coal deflecting fins before distributor.
(F) Line configuration (second alteration).
(G) Two concentric orifices.
(H) Pneumatic distributor.
(I) Directional device with louvres.
(J) Rifled cone.
(K) Pneumatic distributor and rifled cone.

The major portion of these distributors were found to be largely unsatisfactory, although fair to excellent results were obtained with (C), (H), (J), and (K). It is believed that the problem is fairly close to solution, and that a device fulfilling, to a large degree, the requirements of the ideal distributor will shortly be in process of construction. As new distributors were developed at this Plant, information concerning them was furnished to the Fuel Conservation Committee and changes found desirable were made immediately on the *Mercer*.

The pulverized coal tests here described have elicited world wide interest. A very large number of managing directors and engineers visited the Fuel Oil Testing Plant during the period of these runs; an even larger number — including representatives of many foreign shipping interests and shipyards viewed the operation aboard the S. S. *Mercer*.

At this writing the S. S. *Mercer* has completed three successful voyages from New York to Rotterdam and return, with calls at Philadelphia and Boston. Results to date have been so satisfactory that the Shipping Board is making plans for the conversion of several other vessels.

Certain other companies — realizing the advantages of this method of operation have equipped vessels with pulverized coal. The Dominion Coal Company of Canada has recently made an installation on the S. S. *Lingan* using burners and mills similar to those of the third installation at this Plant, while the S. S. *Mississippi Warrior* of the Inland Waterways Commission, also pulverized coal fired, is plying on the Mississippi River.

The number of ships so fired will undoubtedly increase greatly in the near future.

WESTINGHOUSE FORCED DRAFT BLOWER OF THE SCHMIDT PROPELLER TYPE.

By Joseph B. Lincoln and Burnett F. Treat.

In Naval practice, draft in the boilers is customarily produced by putting the locked boiler-room under an air pressure of from six to ten inches of water. This method is conducive to the maximum useful ventilation of the space, at the same time giving a fairly flexible system for supplying the requisite amount of air for the combustion of fuel under the boiler, without space-consuming ducts and machinery on the firing floor. When as much as 20,000 boiler horsepower is often installed in one fire-room, blowers for producing the required draft can be in large individual units, but must necessarily be of a minimum weight and maximum efficiency with absolute reliability. The Schmidt blower was designed with Naval demands in mind, for hanging vertically in the air inlet trunk. The output of the Schmidt blower is in the neighborhood of three times the delivery of the largest plate fans at present used in the Navy, with the same weight.

The following article describes and gives results of tests made at the U. S. Naval Engineering Experiment Station on a Schmidt vertical blower manufactured by the Westinghouse Electric and Manufacturing Company. The unit consists of a non-condensing vertical turbine with a two-bladed fan keyed on the turbine shaft directly above the turbine. The tests covered the performance of the fan at various speeds and capacities, and the performance of the combined unit. No dynamometer tests of the turbine were made, consequently no effort is made to segregate the various efficiencies.

DESCRIPTION OF BLOWER.

A cross-sectional drawing of the blower is shown in Figure 1, and the photograph, Figure 2, shows the unit with only the inlet cone and the fan hub removed. The total weight of the blower is

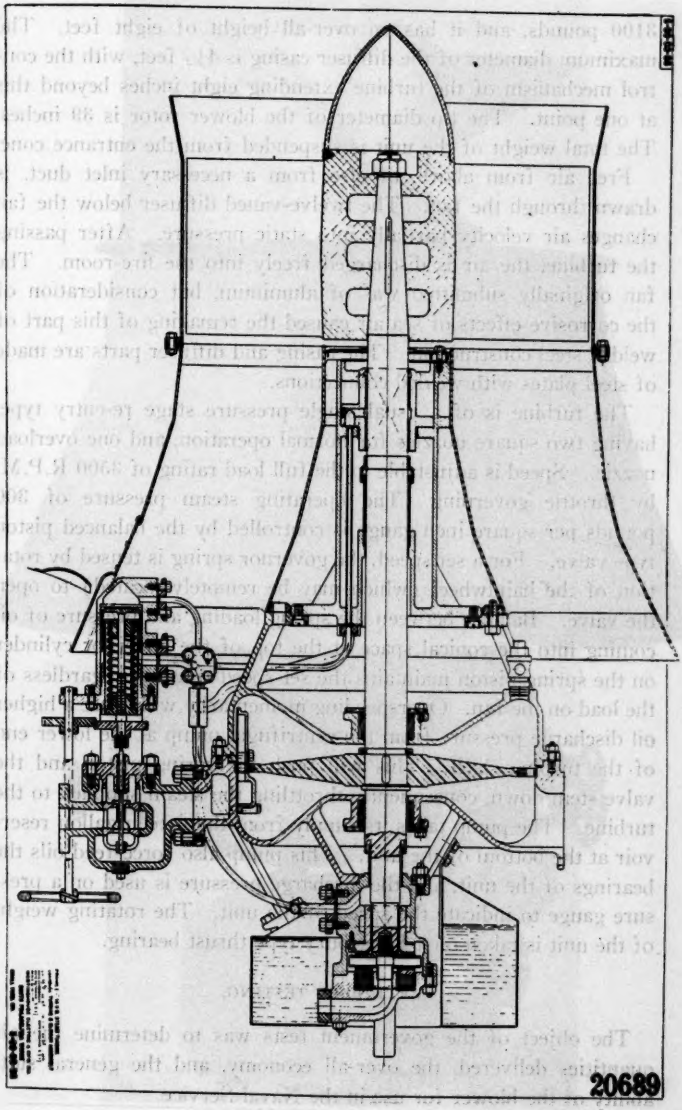


FIGURE 1.

3100 pounds, and it has an over-all height of eight feet. The maximum diameter of the diffuser casing is 4½ feet, with the control mechanism of the turbine extending eight inches beyond this at one point. The tip diameter of the blower rotor is 39 inches. The total weight of the unit is suspended from the entrance cone.

Free air from above, or else from a necessary inlet duct, is drawn through the fan. The twelve-vaned diffuser below the fan changes air velocity partially into static pressure. After passing the turbine, the air is discharged freely into the fire-room. The fan originally submitted was of aluminum, but consideration of the corrosive effects of sea air caused the remaking of this part of welded steel construction. The casing and diffuser parts are made of steel plates with welded connections.

The turbine is of a usual single pressure stage re-entry type, having two square nozzles for normal operation, and one overload nozzle. Speed is adjustable to the full load rating of 3500 R.P.M. by throttle governing. The operating steam pressure of 300 pounds per square inch gauge is controlled by the balanced piston type valve. For a set speed, the governor spring is tensed by rotation of the handwheel (which may be remotely located) to open the valve. Balance between the spring loading and pressure of oil coming into the conical space at the top of the governor cylinder on the spring piston maintains the set speed constant regardless of the load on the fan. Overspeeding momentarily will cause a higher oil discharge pressure from the centrifugal pump at the lower end of the turbine shaft. This will push the spring piston and the valve stem down, consequently throttling the steam supplied to the turbine. The pump takes its supply from the fifteen gallon reservoir at the bottom of the unit. This pump also force-feed oils the bearings of the unit, and the discharge pressure is used on a pressure gauge to indicate the speed of the unit. The rotating weight of the unit is taken on a Kingsbury type thrust bearing.

METHOD OF TESTING.

The object of the government tests was to determine the air quantities delivered, the over-all economy, and the general suitability of the blower for use in the Naval Service.

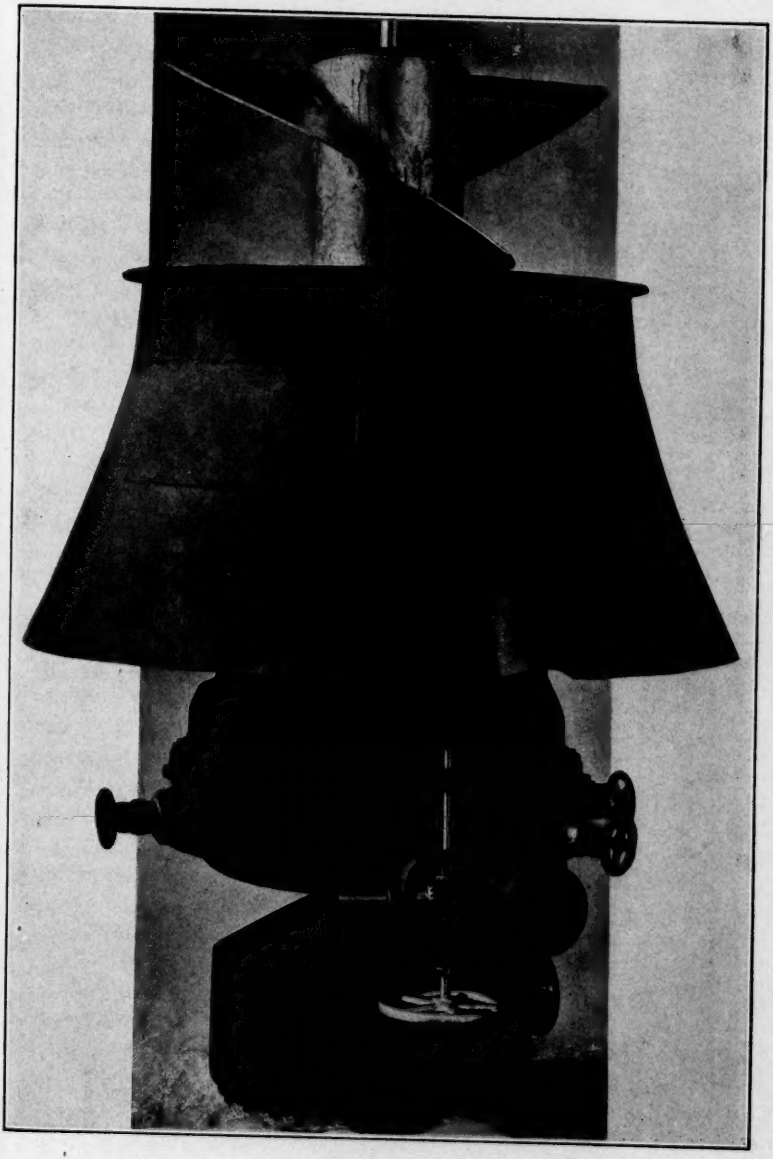


FIGURE 2.

The set-up for test in the manufacturer's plant is shown in Figure 3. Substantially the same arrangement was used at the Experiment Station. The blower was hung from the cone top of a cylindrical sheet metal chamber simulating the fire-room. As shown and as originally used, the air quantities discharged were regulated by the degree of opening in four circular doors in the wall of the chamber. Measurement of the air was made by the impact tube-piezometer ring method at the inlet duct to the fan. The area at the measuring plane was considerably constricted as compared to that at the flared inlet to the duct; so taken as to approximate the vena contracta portion of the air column, and thus have smooth flow across a diameter at the measuring plane.

For the final tests, air quantities were measured with a Venturi meter. A cylindrical duct leading to the meter was attached to the test chamber close to the bottom, and extended radially from the house, ascending at an angle of about fifteen degrees in a vertical plane from the floor. The duct before the meter was 27½ feet long, with an egg-crate section placed in this portion ten feet from the entrance to the meter. The throat section of the Venturi meter proper was a brass casting with a throat diameter of 34.18 inches. From this section sheet metal cone sections spread to the entrance and exit diameters of 56.12 inches. The changes in diameter were made slowly with a smooth interior to the sections for non-turbulent changes in velocity. Static pressure at the entrance was taken with inclined manometers from four holes in the sheet metal wall of the duct, and throat pressure was taken with an inclined manometer from a piezometer ring. An 18⅓-foot extension duct was attached to the outlet side of the meter. The outer end of this duct was flanged for attaching perforated covering plates. With all chamber doors closed, the rate of air flow was varied by using plates with different numbers of holes for covering the outlet. Static pressure within the test chamber was determined as the mean of readings of five manometers placed on the wall and roof of the chamber.

For obtaining steam quantities, the turbine nozzles were individually calibrated to obtain weights of dry steam used at various pressures, and calibration curves were drawn. Steam weights given herein are based on such curves.

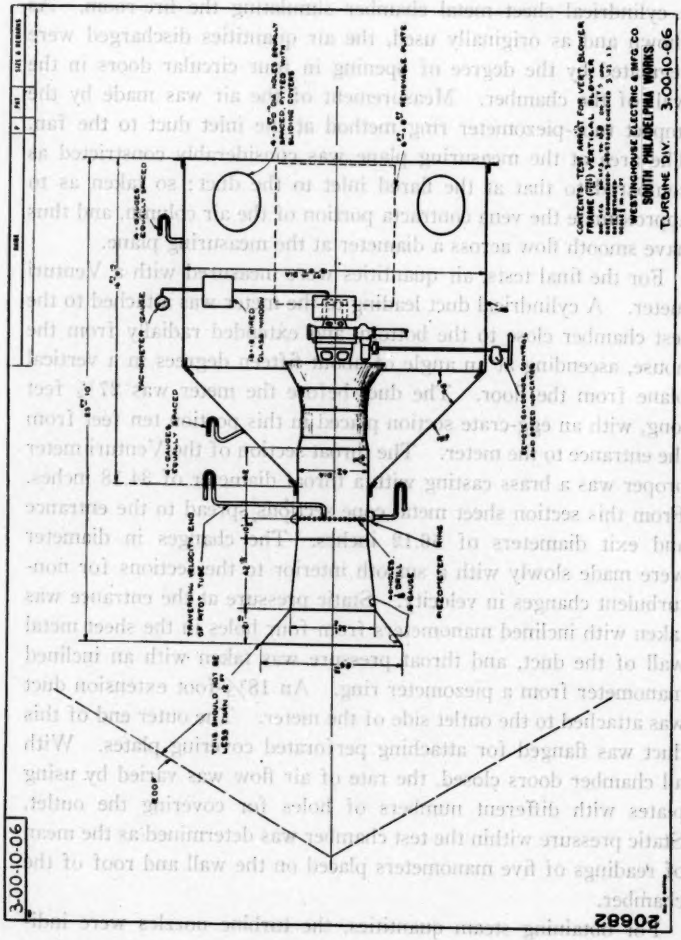

CONTRACT TEST ARRGT FOR VERT BLOWER
FRAME (TEE) VERTICAL BLOWER
WESTINGHOUSE ELECTRIC & MFG CO
SOUTH PHILADELPHIA WORKS
TURBINE DIV. 3-00-10-06
3-00-10-06
20682

FIGURE 3.

The tests made with the Venturi meter comprised main runs at constant speeds of 1250, 1500, 2000, 2500, 3000 and 3500 R.P.M. Speed in each case was set by the speed-graduated oil pressure gauge and a Frahm tachometer, and accurately determined by a revolution counter geared to the turbine shaft. The exhaust pressure from the turbine was maintained constant at 10 pounds per square inch gauge.

RESULTS OF TESTS.

The results of the tests with the Venturi meter are shown in graphic form on Figures 4-8 inclusive. The calibration curve for the pressure gauge type tachometer proposed is shown on Figure 9.

The constant-speed capacity *vs.* head characteristics of the blower are given on Figure 4. The cross-plots of capacity *vs.* speed at constant head are shown on Figure 5. The calibration of the turbine nozzles when discharging into a region where the back pressure is less than one-half the high pressure on the nozzles is shown in Figure 6. On Figure 7 is shown the total steam consumption *vs.* capacity at constant speeds, and Figure 8 gives the steam economy *vs.* capacity.

The following table condenses the operating data and results shown on the figures to give a snap-view of the characteristics of the blower.

Capacity C. F. M.	Delivery Pressure (Static) in. water	Shaft speed R.P.M.	Total Steam lb. per Hour	Steam per 1000 cu. ft. air delivered pounds
30,000	2	1320	1980	1.10
30,000	3	1500	2400	1.33
40,000	4	1820	3000	1.25
60,000	6	2410	4500	1.25
60,000	8	2560	5300	1.47
75,000	8	2840	6400	1.48
75,000	10	2990	7400	1.68
105,000	8	3570	10300	1.64

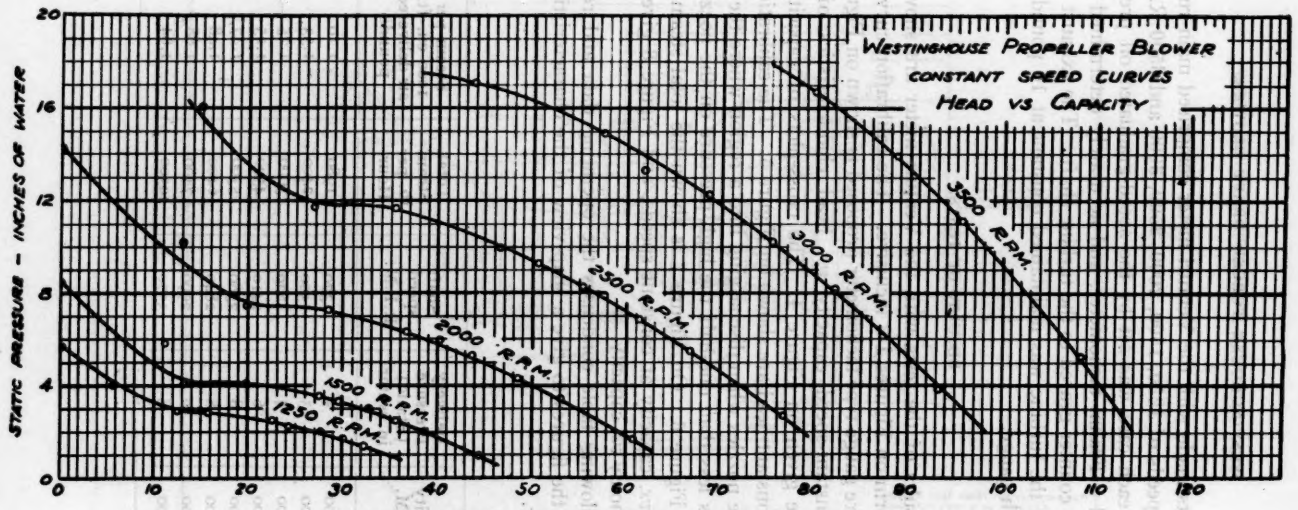

WESTINGHOUSE PROPELLER BLOWER
CONSTANT SPEED CURVES
HEAD VS CAPACITY
STATIC PRESSURE - INCHES OF WATER
AIR DELIVERED - THOUSANDS OF CU. FT. PER MIN.
3500 R.P.M.
3000 R.P.M.
2500 R.P.M.
2000 R.P.M.
1500 R.P.M.
1250 R.P.M.
0
4
8
12
16
20
0
10
20
30
40
50
60
70
80
90
100
110
120

FIGURE 4.

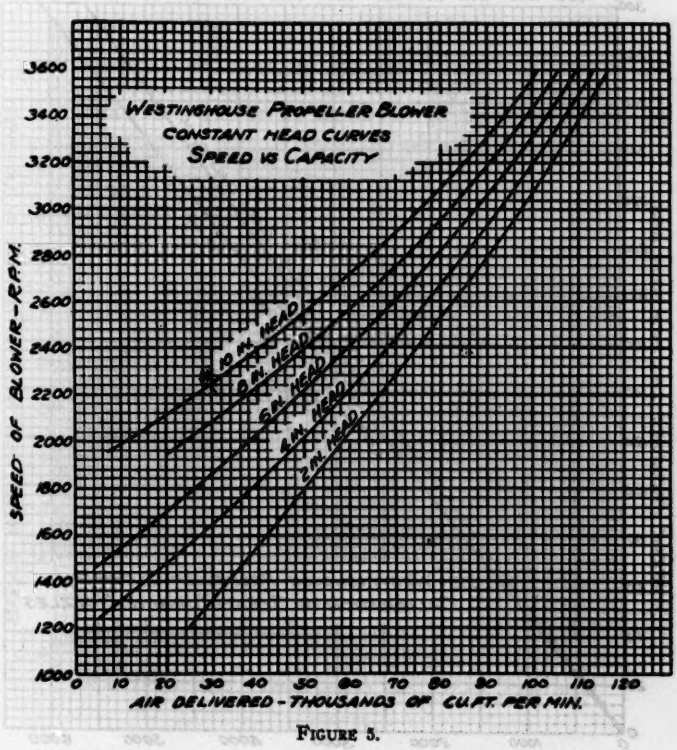

WESTINGHOUSE PROPELLER BLOWER
CONSTANT HEAD CURVES
SPEED VS CAPACITY
SPEED OF BLOWER - R.P.M.
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
10 IN. HEAD
8 IN. HEAD
6 IN. HEAD
4 IN. HEAD
2 IN. HEAD
0 10 20 30 40 50 60 70 80 90 100 110 120
AIR DELIVERED - THOUSANDS OF CU.FT. PER MIN.

FIGURE 5.

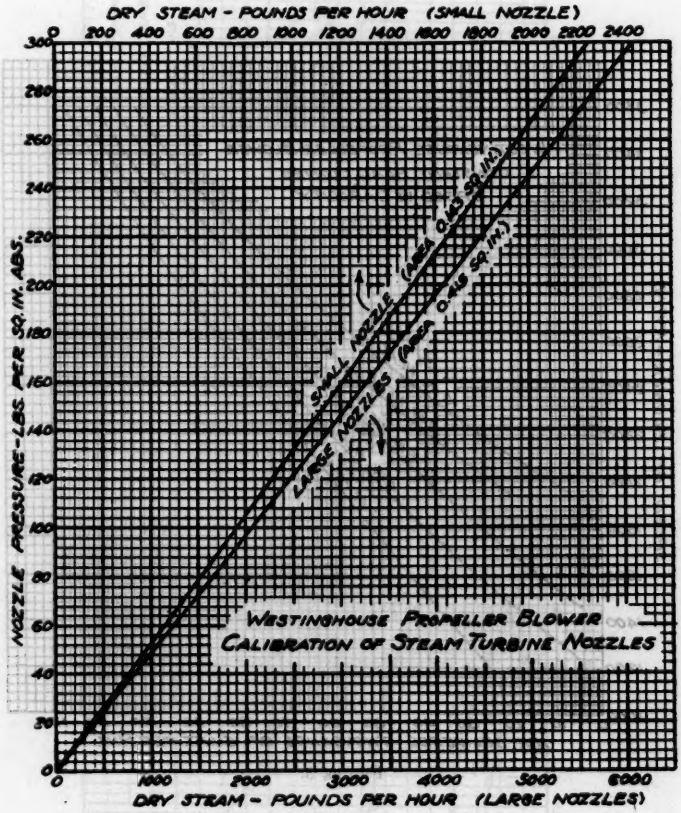

DRY STEAM - POUNDS PER HOUR (SMALL NOZZLE)
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400
300 280 260 240 220 200 180 160 140 120 100 80 60 40 20 0
NOZZLE PRESSURE - LBS. PER SQ. IN. ABS.
SMALL NOZZLE (AREA 0.05 SQ. IN.)
LARGE NOZZLES (AREA 0.445 SQ. IN.)
WESTINGHOUSE PROPELLER BLOWER
CALIBRATION OF STEAM TURBINE NOZZLES
0 1000 2000 3000 4000 5000 6000
DRY STEAM - POUNDS PER HOUR (LARGE NOZZLES)

FIGURE 6.

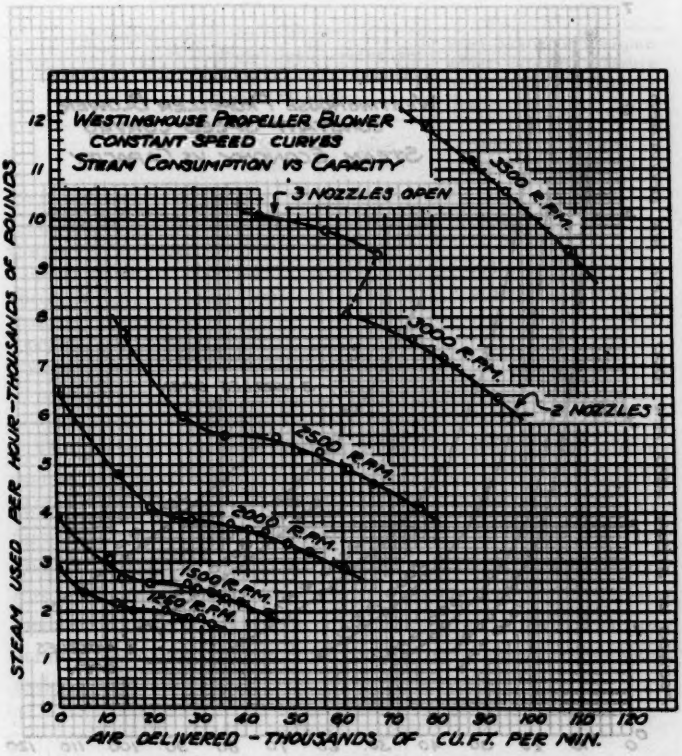

WESTINGHOUSE PROPELLER BLOWER
CONSTANT SPEED CURVES
STEAM CONSUMPTION VS CAPACITY
3 NOZZLES OPEN
3500 R.P.M.
3000 R.P.M.
2 NOZZLES
2500 R.P.M.
2000 R.P.M.
1500 R.P.M.
1250 R.P.M.
STEAM USED PER HOUR-THOUSANDS OF POUNDS
AIR DELIVERED - THOUSANDS OF CU.FT. PER MIN.
0 10 20 30 40 50 60 70 80 90 100 110 120
0 1 2 3 4 5 6 7 8 9 10 11 12

FIGURE 7.

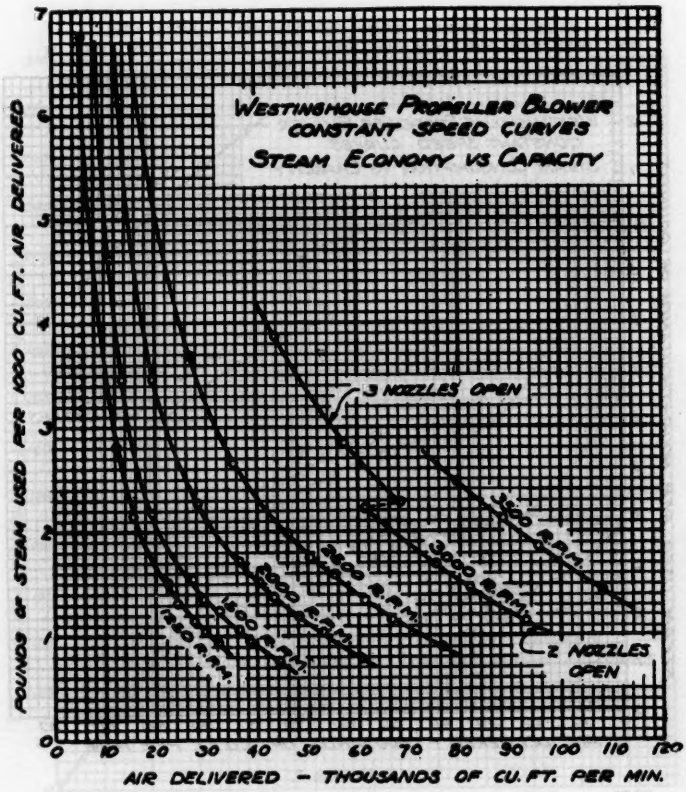

WESTINGHOUSE PROPELLER BLOWER
CONSTANT SPEED CURVES
STEAM ECONOMY VS CAPACITY
POUNDS OF STEAM USED PER 1000 CU. FT. AIR DELIVERED
AIR DELIVERED - THOUSANDS OF CU. FT. PER MIN.
3 NOZZLES OPEN
2 NOZZLES OPEN
3600 R.P.M.
3200 R.P.M.
2800 R.P.M.
2400 R.P.M.
2000 R.P.M.
1600 R.P.M.
1200 R.P.M.
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70
80
90
100
110
120

FIGURE 8.

In order to determine the effect of closing off the inlet to the blower, a wooden plug was made to fit into the inlet. While the blower was running this plug was suddenly inserted. The following data were obtained on several such tests.

	With control valve set to give 1960 R. P. M. with open inlet		With control valve open wide. Nozzle pressure held constant by throttling	
	Inlet open	Inlet closed	Inlet open	Inlet closed
Air quantity, C.F. M.	61,000	0	63,000	0
Discharge pressure, inches water	0.8	0	0.8	0
Speed, R.P.M.	1960	1880	2040	1380
Nozzle pressure, pounds per square inch	73	147	79	79

The question of noise, whereas minor to considerations already pointed out, is sufficiently important to deserve note. The Schmidt blower emits, increasing with the speed, a rather depressing sustained whirr of a low pitched note. Lacking shrillness this noise does not carry far, and is not even initially objectionable to auditors. The continuity of the low roar becomes wearing to sensitive persons in close range, but would probably be unnoticed on long familiarity, or by personnel physically busy among other noise making apparatus.

CONCLUSIONS.

A blower, to be entirely safe for Naval installation, should be capable of operating without damage on shutting off the inlet. On stoppage of the inlet to the Schmidt blower there was a decrease in the rotative speed in every case, showing that an increase in load results from simple churning of the air over the load of normal operation. It is evident that the unit cannot overspeed to do damage on shutting of the damper.

The speed-graduated pressure gauge operated by the oil discharge of the centrifugal pump proved to be sufficiently accurate for speed indication provided a good grade of test gauge was used. Inasmuch as there was some question as to the effect of viscosity on the pressure readings, the gauge was calibrated over a range of speeds with a light oil and with a medium heavy oil having respectively viscosities of 200 and 500 seconds Saybolt Universal. The results as shown on Figure 9 indicate that this range in viscosity does not affect the calibration. This method of speed indication should prove satisfactory and sufficiently accurate for operating purposes.

The head *vs.* capacity curves given on Figure 4 show a relatively steep continuously rising characteristic. When operating on such a characteristic, two blowers like the one tested should operate in parallel very satisfactorily. Parallel operation of this type blower

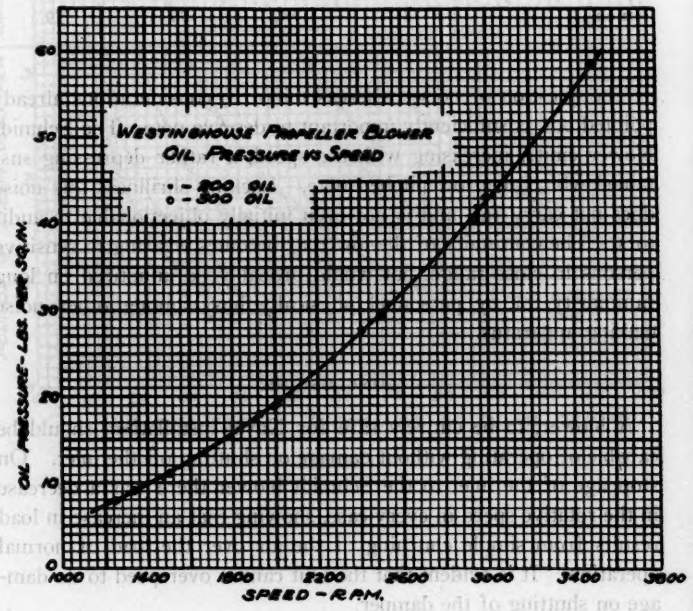


FIGURE 9.

with another type blower may or may not be practicable depending on the characteristics of the blowers, and can only be determined when so installed.

It is intended, where two or more blowers are installed in a single fire-room, to interconnect the governors of all the blowers and control them from a single handwheel. Thus, when the speed adjustment is changed, this change is made simultaneously to all the governor springs, whether or not all the blowers are running. Consequently, if one blower is running and another is shut down, in order to bring the idle blower in parallel with the operating blower it will only be necessary to open the throttle valve wide on the idle blower, whereupon it will come up to the same speed as the blower which has been running, and the two blowers are synchronized without any attention on the part of the operator. Graduation marking on the remote master control handwheel permits the speed setting to be made directly, having recourse to the tachometer only as a check on the speed.

The results given are all for measurements with the Venturi meter. The static pressures observed and used in calculating the results of the tests are the true static pressures in the test house uncorrected for any velocity head in the discharge or intake of the blower, and no correction for pipe friction in the intake pipe was added. The results of the initial method of measurement with the impact tube so nearly coincided with those obtained with the more accepted Naval Engineering Experiment Station method of Venturi meter measurement that only the latter is cited.

The Schmidt blower has qualities which make it highly adaptable to power plant use, particularly for such use in the Naval Service. The most vital of these qualities is low steam consumption per unit output; followed by qualifications only a little less important, light weight for unit output, rugged reliability, safety, and ability to operate in parallel.

HISTORY, DESCRIPTION, AND ACCEPTANCE TRIALS OF THE U. S. S. *LEXINGTON.*

By Commander C. S. Gillette, U. S. Navy, Member.

The U. S. S. *Lexington* and her sister ship, the U. S. S. *Saratoga,* are unique, not only that they are the first Airplane Carriers ever constructed for the U. S. Navy, other than experimental types, but further in that they are propelled by the most powerful machinery ever put into the hull of a vessel in the history of the World. Not only that, but in combined power, as well as in the power of the individual propulsion units, the machinery compares most favorably with the largest shore power plants ever completed to date.

In so far as the writer is informed, the most powerful machinery plant in any war vessel, other than the *Lexington* and *Saratoga,* is that of the battle cruiser, H. M. S. *Hood,* of the British Navy, which was laid down with a designed shaft horsepower of 144,000 at 31 knots; on trials, the *Hood* is credited with having developed 151,000 shaft horsepower at 32.07 knots with a displacement of 42,200 tons. While in the merchant vessel class, the most powerful machinery plant appears to be that of the S. S. *Leviathan,* which is credited with approximately 100,000 shaft horsepower. The designed shaft horsepower of the *Lexington* is 180,000 at 317 propeller R.P.M. (33.7 knots).

This vessel was so long in building that it may be as well to review briefly the history of her design and construction.

The acts making appropriations for the Naval Service for the fiscal years ending June 30, 1917 and 1918, approved respectively, August 29, 1916, and March 4, 1917, authorized the construction of five battle cruisers. A state of war having been declared between the United States and Germany by joint resolution of Congress on April 6, 1917, an order (Contract 301) was placed by the

President on the Fore River Shipbuilding Corporation on April 26, 1917, for the construction of Battle Cruiser No. 1 (the *Lexington),* on a " cost plus ten per cent" basis.

The plans and specifications for Battle Cruiser No. 1 specified the installation of electric propulsion machinery, and the Fore River Company, shortly after receiving the foregoing order, entered into a contract on a fixed price basis with the General Electric Company of Schenectady, New York, to supply the propulsion machinery required. The Navy Department then entered into a supplementary contract (Contract 564), dated July 17, 1917, with the latter company covering guarantees as to specifications and the performance of the machinery to be furnished for propulsion purposes.

Work under the above contract was nearing completion when, on February 8, 1922, work was suspended thereon by the Navy Department pursuant to international agreement reached at the Disarmament Conference at Washington, D. C. Under the Act of July 1, 1922, the President was authorized to undertake the conversion of Battle Cruiser No. 1 to Airplane Carrier No. 2 and a supplementary contract (Contract No. 301-A) was concluded on November 2, 1922, between the Navy Department and the Fore River Shipbuilding Corporation for the completion of the vessel as an Airplane Carrier. Work under the original contract, on such parts of the vessel as were common to both battle cruiser and airplane carrier, had been allowed to proceed under authorization of the Navy Department on July 13, 1922. On December 26, 1922, a further supplementary contract was concluded between the Navy Department and the General Electric Company which modified extensively the guarantees previously made for the propulsion machinery in view of the conversion to an airplane carrier. The price for the work was also substantially increased.

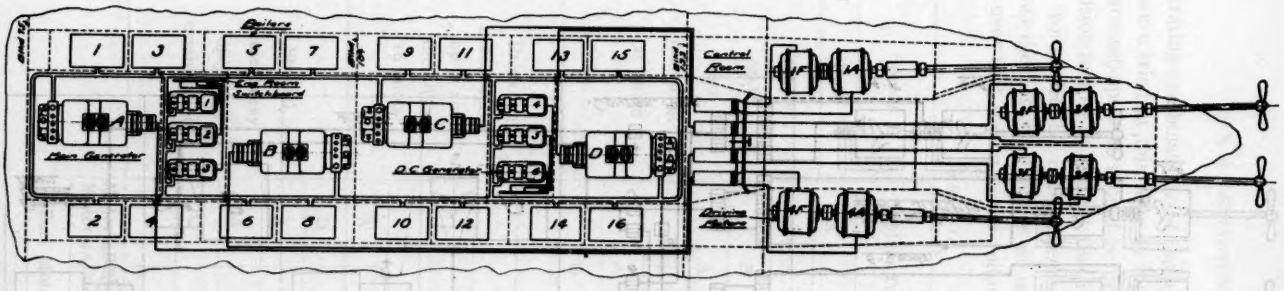
The final contract price for the electrical propulsion equipment was $3,086,856.08. One naturally wonders what item that final eight cents covered.

It may also be of interest to record that on December 7, 1920, the Navy Department agreed by a letter, made part of the contract, to the proposal of the Fore River Shipbuilding Corporation that

the "cost plus ten per cent" feature of the original contract be discontinued as from the beginning in favor of a "cost plus fixed fee" basis of compensation. The fixed fee for profit was agreed upon at $2,000.000.00, the Department further waiving claim to certain permanent improvements made to the contractor's plant which had been originally allowed as part of the cost of construction of the vessel.

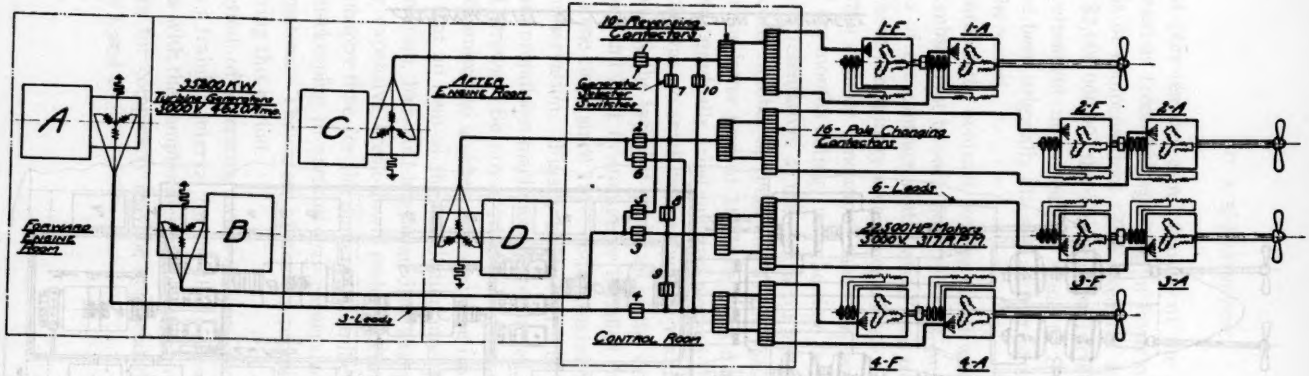
A feature of the contract for the vessel was that, upon completion and subsequent to such dock trials as could be carried out at the works of the contractor, the vessel was to be delivered to the Navy without preliminary acceptance trials. Guaranteed performance, within definite limitations, however, was stipulated over a period of six months dating from the time the vessel was accepted by naval representatives at the contractor's plant. The *Lexington* was launched October 3, 1925, and as the vessel neared final completion in the latter part of 1927 the great mass of auxiliary machinery was gradually tried out and worked into operating condition. This was no small task as will be realized when consideration is given to the fact that nearly all of the various units had been constructed and kept in storage or installed on board for several years, in some cases since 1918, under conditions most difficult for efficient preservation. Finally in October, 1927, preliminary trials of the main propulsion machinery were started, operating with disconnected screws. Before starting this series of trials, every preliminary examination and test that could be made were carried out to insure that no item of the installation, and particularly all electrical insulation, had not deteriorated at any point sufficiently to cause any expensive break-down under operating conditions. It was an unhappy time for the numerous families of rats which had set up housekeeping in various cozy corners of the main alternators and motors. The career of many a promising young rat was ruined during this period.

The period of operating with disconnected screws was also utilized as a training interval for the ship's personnel to familiarize themselves with the complexities of the switching equipment. The possibilities for complexity may be appreciated by a brief glance at Figures 1 and 2.



ARRANGEMENT OF MAIN PROPULSION MACHINERY

FIGURE 1.



DIAGRAMATIC SKETCH OF MAIN PROPULSION CIRCUITS

FIGURE 2.

All the operating combinations of main alternators and propulsion motors were tried at this time as indicated by the following table of selector set-ups. It should be understood that the selection of propulsion motors to be used, that is, any one, both, or none per shaft, is controlled by independent switches in the control room, and thus the possible number of combinations is increased several times over that shown in the following table:

TABLE I.

Selection No.	Speeds	Main Turbo-Alternators in use			
1	Full	A	B	D	C
2	From 19 up to and including 25 knots	A		B	
3		B		D	
4		A		D	
5		B		C	
6		A		C	
7		D		C	
8	From the lowest speed up to and including 19 knots	A			
9		B			
10		C			
11		D			
12	Special emergency operating combinations	A	D		C
13		D	B		C
14		A	B		C
15		A	D		B
16		C	B	D	C
17		A	B	D	A
		Motor-4F Motor-4A	Motor-3F Motor-3A	Motor-2F Motor-2A	Motor-1F Motor-1A
		Port Motors		Starboard Motors	

Eventually, in November, 1927, the screws were coupled to the shafts and dock trials under power were carried out. All of the propulsion circuits had previously been brought up to maximum operating voltage, and all had been tried with full operating current, so the dock trials under power, that is, using voltage and current together, could safely be limited in extent with reasonable assurance of safe operation underway. Maximum operating speed of both motors and alternators had been reached with disconnected screws several times in preliminary tests so that satisfactory operation of the bearings was assured. Considerable anxiety was felt by all concerning the attempt to absorb even a small percentage of the maximum power of such a plant with the screws while alongside the dock.

Indicators were placed about the dock to show changes in the bottom while operating with the screws, and numerous observers were stationed. Operation under various combinations was then attempted during several days and a maximum power of about 10,000 kilowatts at the alternator was absorbed by the screws, and a maximum propeller speed of approximately 90 R.P.M. was attained for a short time. Most of the testing, however, was down at a propeller speed of approximately 55 R.P.M. This permitted necessary governor adjustments of the main turbo-alternators and observations of the minimum pull-in speeds required under operating conditions.

The vessel was tentatively accepted and commissioned by the Navy Department on December 14, 1927, Captain A. W. Marshall, U. S. Navy, taking command. Completion of unfinished items of work by the contractor and preparation and training of the Naval crew for handling the vast ship through the draw of the bridge at Fore River, and via the tortuous channel to the drydock at South Boston, occupied the time until January 5, 1928.

For months prior to the attempt to bring the *Lexington* to Boston from the Fore River Plant, the newspapers of the country carried comment and discussion on the subject from every point of view. In general, the consensus of opinion seemed to be that somebody had made a serious error in judgment in permitting the construction of such a vessel so far from water suitable for its safe

navigation, and many were the predictions as to the troubles and even disastrous results that would inevitably be experienced when the move was attempted. In all truth, the problem was not a simple one as any one acquainted with the route to be followed from Fore River to South Boston can testify, particularly when the dimensions of the *Lexington* are considered. Let us glance at these dimensions —

Length over all, 888 feet.

Breadth, maximum, 106 feet.

Depth, flying deck to keel, 74 feet 3 inches.

Four smoke pipes, fully enclosed, 79 feet above flying deck, and approximately 110 feet in length, an excellent sail, aided by bridge structure and turrets.

Draft for this movement only 28 feet.

The actual width of the draw through which the vessel had to pass was 120 feet, with a sharp turn to starboard the moment the stern cleared the draw to avoid too intimate an association with a coal yard just beyond.

The conditions required that the move be started at high water slack with plenty of daylight for the entire trip, clear weather for ranges, no ice to speak of and no wind; difficult conditions, these, for Boston in January. However, the necessary conditions materialized on January 5th, all, that is, except the one in regard to wind. Even this latter condition held for a time as the ship backed into the stream from the Fore River Dock slightly ahead of high water slack on a bitter cold morning. But when the movement was so far advanced that there was no turning back, a breeze of about twenty to twenty-five knots sprang to life blowing directly across the draw where its full force could be expended on the giant enclosed stack structure to the worst effect. True, there was a multitude of tugs, but they had to be dropped off as the vessel negotiated the draw. It was not intended to use the engines of the vessel, except in emergency, until the draw was cleared and the ship pointed fair for the channel, and it had not even been permitted to try them out before the movement was started. However, the emergency condition soon came, and the first signal the engines of the *Lexington* ever received was signalled in the middle of the draw for two-thirds astern.

The incidents of the first voyage were highly interesting and no one who experienced them is likely to forget in a hurry. It will be to the everlasting credit of those who handled the ship that day, particularly to the veteran pilot, Captain Kemp, that the voyage was made in safety, without mishap and with no injury to any part of the ship, or other property, if one is willing to overlook the caressing touch of the ship on a trolley pole or so at the end of the draw. It may be illuminating to record that the number of engine signals received over that brief voyage of about five miles was something over one hundred, and at the end of it those handling the engines in the control room were still even with the engine order telegraph.

The *Lexington* then entered the drydock at South Boston for a final clean up of work before starting her shake-down cruise to the Pacific Coast where her final acceptance trials were to be held.

DESCRIPTION.

The general layout of machinery may be understood by reference to Figures 1 and 2, preceding. The following items are taken up following the U. S. Navy Filing Manual for convenient reference:

CLASS S1 — GENERAL HULL FIXTURES.

The profile of the *Lexington* resembles that of the *West Virginia* class of battleships; distinctive features are the fully enclosed stacks, the tripod supported bridge structure, the anti-aircraft gun galleries, and the boat pockets let into the side of the vessel under the level of the flight deck. Turrets, bridge structure, and stacks are installed on the extreme starboard side with only a narrow passage between them and the starboard rail. The overweight on the starboard side is compensated by fuel oil, or other suitable ballast on the port side. The port boiler uptakes reach the stacks by horizontal, venturi shaped cross-overs, four in number, passing athwartship just above the level of the third deck.

The flight deck extends the entire length from bow to stern, ending with a sloping ramp aft; the whole surrounded with life nets, wind barriers, and landing nets appropriately placed. This deck is equipped with all the necessary facilities for handling air-

planes both off and on, including catapult, deck fittings for securing airplanes, illumination, airplane crane, and arresting gear. The deck is served by two hydraulic elevators from the hangar space beneath.

The majority of the crew are housed on the main deck from frame 67 to the stern. This space also includes the galleys, wash rooms and other facilities for the care of the crew. The remainder of the crew are housed outboard of the hangar space, mainly on the port side, and on upper half deck, middle half deck, and second deck.

The officers are housed forward from frame 67 on the main deck, upper half deck, and middle half deck. Windlass room, chain lockers, boatswain's stores, etc., occupy the space on above decks forward of frame 14.

The third deck is armored and all the machinery compartments are entered from this deck.

Air for the forced draft blowers may be taken from doors opening outboard on the starboard side protected by spray shields, or from doors opening off the hangar space inboard. On the port side air may be taken from suitable ducts opening into the boat pockets and vicinity, or also from doors opening off the hangar space inboard.

The outside air for cooling main alternators and propulsion motors is not needed as the cooling systems of these units are unique in that they are self-contained and water cooled.

The designed complement is as follows:

Total Commissioned Officers	169
Total Warrant Officers	22
Total Enlisted Personnel	1708

CLASS S16-4 — ACCESS LADDERS AND GRATINGS.

In general all access ladder treads are of cast aluminium alloy.

Gratings throughout the Engineer Department and elsewhere are of the reticulated "subway" type and fabricated from a corrosion resisting aluminium alloy. In many cases the reticulated type of grating has not been found satisfactory from the standpoint of protection from falling dirt, and sheet metal screens have been placed

underneath at many points. In many cases, cast aluminium alloy plating with suitable anti-skid surface would appear to be preferable.

CLASS S16-5 — ELEVATORS.

There are elevators installed as follows:

(*a*) One airplane elevator, double hydraulic piston type, supplied by Otis Elevator Co., with full load capacity of 16,000 pounds, and speed of 60 feet per minute at 12,000 pounds load.

(*b*) One airplane elevator, single hydraulic piston type, supplied by Otis Elevator Co., with full load capacity of 6000 pounds, and speed of 120 feet per minute at 5000 pounds load.

(*c*) One freight elevator, electric type, supplied by Otis Elevator Co., with capacity of 3360 pounds, at a speed of 120 feet per minute.

(*d*) Four dumb waiter elevators, electrically operated.

CLASS S19-1 — PAINTING.

Aluminum paint as per the latest standard of the Bureau of Construction and Repair, viz.: aluminum mixing varnish and aluminum powder, has been used extensively throughout the Engineer Department of the vessel for heated surfaces, and for retouching galvanized coatings where destroyed during fabrication of sheet metal structures; excellent results have been obtained with this paint to date.

CLASS S22 — STEERING GEAR.

The steering gear is of the electric-hydraulic type, consisting of eight 24-inch hydraulic rams directly connected to the rudder by thrust rods and connecting rods. Hydraulic pressure is supplied by two 150 H.P. Waterbury variable stroke oil pumps directly connected to a 300 H.P. shunt wound D. C. motor. The rams deliver a torque to the rudder of 75,000,000 inch-pounds with a pressure of 1000 per square inch in the hydraulic cylinders. With ship going ahead at 31 knots the rudder may be moved from hard-over to hard-over in 30 seconds. Any one or any pair of hydraulic cylinders may be cut out without interfering seriously with the operation.

The electrical equipment includes the above main driving motors and panel, also the pilot motors for handling the tilting box of the Waterbury, which are in duplicate. In general, except for size, the equipment is similar in almost all respects to that installed on the latest battleships.

Emergency operation of the main drive motors is provided for by a 900 ampère hour storage battery installed in an adjacent compartment. Automatic relays cut the battery in and out with failure or return of ship's power voltage. Overload conditions are cared for by overload and step-back relays.

In addition to trick wheel and hand control which operate the tilting box directly, the ship may be steered from, (*a*) pilot house, (*b*) conning tower, (*c*) secondary conning tower, (*d*) central station, and (*e*) steering control room aft. The equipment was supplied by the American Engineering Company of Philadelphia. The electric motors and controllers were supplied by the General Electric Co., and the variable stroke oil pumps by the Waterbury Tool Co.

CLASS S24-7 — NAVIGATIONAL INSTRUMENTS.

Gyro Compasses — Two Arma Mark III master gyro compasses with motor generators, starting panels, and repeater panels are installed. There are twenty-six repeaters which may be operated from either master.

Electric Log — The electric log is of the pitot tube type known as the "Sal Log" and was supplied by the Svenska Aktiebolaget Co., of Stockholm, Sweden.

A complete anemometer system is installed.

Two electric driven deep sea sounding machines are also furnished.

A "fathometer" electrical depth finding outfit is installed.

CLASS S26-1 — (MOORING) ANCHOR ENGINE AND CAPSTANS.

The anchor engine was supplied by the Hyde Windlass Company of Bath, Maine, and consists of two 150 H.P. D. C. motors driving through two sets of reduction gearing the horizontal shaft of the windlass to which the three wildcats and the gypsy heads

may be clutched. Hand, air, and electric dynamic braking is available.

There is a control panel for each motor with individual sets of starting resistances. Overload conditions are cared for by overload and step back relays.

There are three master controllers in different locations, all identical, and the motors may be controlled in the following hook-ups:

(*a*) Either motor driving windlass.

(*b*) Both motors in series driving windlass.

(*c*) Both motors in parallel driving windlass.

In general, the motors are run in series for heaving short, in parallel for heaving in, and in series for housing. Series connection may be needed to break anchor clear.

Hoisting capacity: Two 30,000-pound anchors from 60 fathoms at the rate of 6 fathoms per minute.

There are four *hydraulic capstans* installed on the main deck at frames 39, 47, and 181-182 on port and starboard sides. These were supplied by the American Engineering Company and are identical, each operated by a 60 H.P. shunt wound D. C. motor driving a hydraulic variable stroke oil pump of the Waterbury type.

CLASS S27 — DECK WINCHES.

Two electric driven deck winches are installed, one on the flight deck at frame 90, and one on the upper half deck at frame 138. These were supplied by the Flory Company of Bangor, Pa., and each has a capacity of 4000 pounds, at 200 feet per minute or 16,000 pounds at 50 feet per minute. The motors are by the Diehl Electric Co., and are 43.75 H.P., compound wound, D. C. type.

CLASS S30-2 — GASOLINE STOWAGE.

Gasoline is stored in storage tanks similar to the fuel oil storage tanks, surrounded by ventilated voids. A salt water exchange system is used in withdrawing the gasoline from these tanks. The total capacity of gasoline carried is 163,000 gallons.

CLASS S32-9 — PRINTING EQUIPMENT.

The following electric motor driven equipment is installed in the print shop:

One linotype machine — Mergenthaler Linotype Co., Boston, Mass.

One job press — Chandler and Price Co., Cincinnati, Ohio.

One saw trimmer — Emerson Electric Co., St. Louis, Mo.

One wire stitcher — Latham Machinery Co., Chicago, Ill.

One paper cutter — Goulding Mfg. Co., Franklin, Pa.

CLASS S33-6 — SHOE REPAIR EQUIPMENT.

The following electrical equipment is installed in the shoe repair shop:

One shoe repair machine — American Shoe Machine Co., St. Louis, Mo.

One shoe repair electric heater—General Electric Co.

CLASS S34 — COMMISSARY EQUIPMENT.

Bake ovens, bakery: Three Navy Standard Bake Ovens, 17.2 Kw. each, by the Edison Electric Appliance Co., Chicago, Ill.

Bake ovens, officers' galley: Two as above, 8.1 Kw. each.

Bake ovens, crews' galley: Two as above, 10.2 Kw. each.

Dish washer: Spray type, by the Champion Dishwasher Machine Co., of Rochester, N. Y., compound D. C. motor driven.

Dish sterilizer: By the Insinger Co., of Philadelphia, 2 H.P. D. C. motor drive.

Dough mixer: By the Century Machinery Co., of Cincinnati; 3 H.P. compound D. C. motor drive.

Electric ranges: By the Edison Electric Appliance Co., of Chicago, Ill., in number and capacity as follows:

One — Admiral's	12.5 Kw.
One — Captain's	12.5 Kw.
Four — Ward Room and J. O. Galley, 16 Kw. each	32.0 Kw.
One — Warrant Officers' Galley	14.0 Kw.
One — Diet Kitchen	6.0 Kw.
Eight — Crews' Galley, 16 Kw. each	128.0 Kw.
Total	205.0 Kw.

Maximum galley heating demand including bake ovens is therefore 293.2 Kw.

Kettles, steam jacketed: By the Aluminum Cooking Utensil Co., of New Kensington, Pa., in number and capacity as follows:

Two — 60 gallons capacity.

Nine — 80 gallons capacity.

Kitchen and cake machine: By the Reed Machine Co., of York, Pa., 1 H.P. compound D. C. motor drive.

Vegetable peelers: Two — by the Imperial Foundry and Machine Co., of New York City, 1.5 H.P. compound D. C. motor drive.

Meat grinder: By the Hobart Mfg. Co., of Tory, Ohio, 1.2 H.P. motor drive.

Coffee urns, steam jacketed: By the Aluminum Cooking Utensil Co., of New Kensington, Pa., Navy Standard Type in number and capacity as follows:

Three — 120 gallons capacity.

One — 20 gallons capacity.

One — 40 gallons capacity.

Coffee grinder: By the A. J. Deer Co., of Hornell, N. J., ¼ H.P. motor drive.

REFRIGERATORS.

"Frigidaire" type, by the Bohn Refrigerator Co., of Boston; each driven by ⅓ H.P. 120 volt, compound wound D. C. motor; number and capacity as follows:

Two — Admiral's and Captain's Pantries, 10.8 cubic feet capacity each.

Two — Ward Room Pantry, 20.2 cubic feet capacity each.

Two — Junior Officers' Pantry, 20.2 cubic feet capacity each.

One — Warrant Officers' Pantry, 20.2 cubic feet capacity.

Two — C. P. O. Pantry, 20.2 cubic feet capacity each.

One — Butcher Shop, 20.2 cubic feet capacity.

CLASS S35-2 — LAUNDRY EQUIPMENT.

All of the following items are supplied by the American Laundry Machinery Co., of Rochester, N. Y.

One — Collar shaper, motor drive, ¼ H.P.

One — Ironer, collar and cuff, motor drive, 1 H.P.

One — Starch steam cooker, 15 gallons capacity.
One — Drier, motor drive, ½ H.P.
One — Ironer, flat work, motor drive, 3 H.P.
Two — Extractors, motor drive, 3 H.P. each.
One — Tumbler drier, motor drive, 3 H.P.
Two — Washers, motor drive, 2 H.P. and 3 H.P. respectively.
Four — Clothes presses, steam.

CLASS S36-1 — WATER HEATERS.

The showers and baths throughout the ship as well as other points where hot water is required are supplied with thermostatic mixing valves, furnishing hot water as required by direct mixture with steam. These mixing valves are supplied by the Leonard-Rooke Co., of Providence, R. I., and are rated at 7 gallons per minute at 40 pounds per square inch gauge; inlet, ¼ inch; outlet, ¾ inch I.P.S.

CLASS S36-3 — SCUTTLE BUTTS.

Five scuttle butts are installed with capacity of 75 gallons each; cooling coil is furnished with each, connected to ship's refrigerating system.

CLASS S36-4 — INCINERATOR.

Garbage incinerator of the "Jockers" type, oil burning, is installed, and air supplied from 20 H.P., compound D. C. motor driven air compressor of 100 cubic feet capacity, 40 pounds per square inch operating pressure; compressor by Chicago Pneumatic Tool Co., and motor and controller by General Electric Co. Air can also be furnished from ship's pneumatic system.

CLASS S37-2 — MEDICAL EQUIPMENT.

One — Incubator, Central Scientific and Electric Co., 120 watts.
Two — Instrument sterilizers, Cutler-Hammer Co., and Promethias Electric Appliance Co.
Three — Electric sterilizers, American Sterilizer Co., Erie, Pa., 6000 watts each.
Three — Electric water heaters, American Sterilizer Co., Erie, Pa., 6000 watts each.

Four — Electric heated dressing containers, American Sterilizer Co., Erie, Pa.

Two — Dental outfits, complete, motors by Emerson Electric Co., and General Electric Co.

CLASS S38-1 — VENTILATING SETS.

Ventilating sets are furnished as supply and exhaust for most of the compartments of the vessel, and in many cases are combined with heater boxes in thermo-ventilating units as a part of the heating system. In the following is a summary of the ventilating plant. The heater boxes are in all cases supplied by the Sturtevant Co., of Hyde Park, Mass., and, in the majority of cases, the ventilating blowers were also supplied by this company. The designed steam pressure for the heater boxes is 35 pounds per square inch gauge. All motors are shunt wound for 230 volts, D. C.

CLASS S38-2 — HEATING.

The thermo-ventilating heaters are summarized under Class S38-1. There is in addition a comparatively small number of steam radiators of the usual type, together with a few electric air heaters, and a large number of electric radiant heaters for staterooms and baths:

CLASS S41-1 — MAIN PROPELLING MACHINERY — TURBINES.

The turbines driving the four main alternators used for propulsion are shown in cross section, Figure 3. Each turbine is rated as follows: 35,200 Kw., 1755 R.P.M., 13 stage, straight impulse type, for use with 265 pounds per square inch steam pressure with 50 degrees F. superheat at the throttle, and 28.5 inches of vacuum. Supplied by General Electric Co.

A balanced throttle and trip valve is placed in the steam supply for use when shutting down, or starting, and in emergency. When operating under the control of the control room, the throttle valve is wide open, and controlling valves, operated by the governor, regulate the steam supply. The controlling valves are operated by a cam shaft which is rotated by a pinion meshing with a rack on

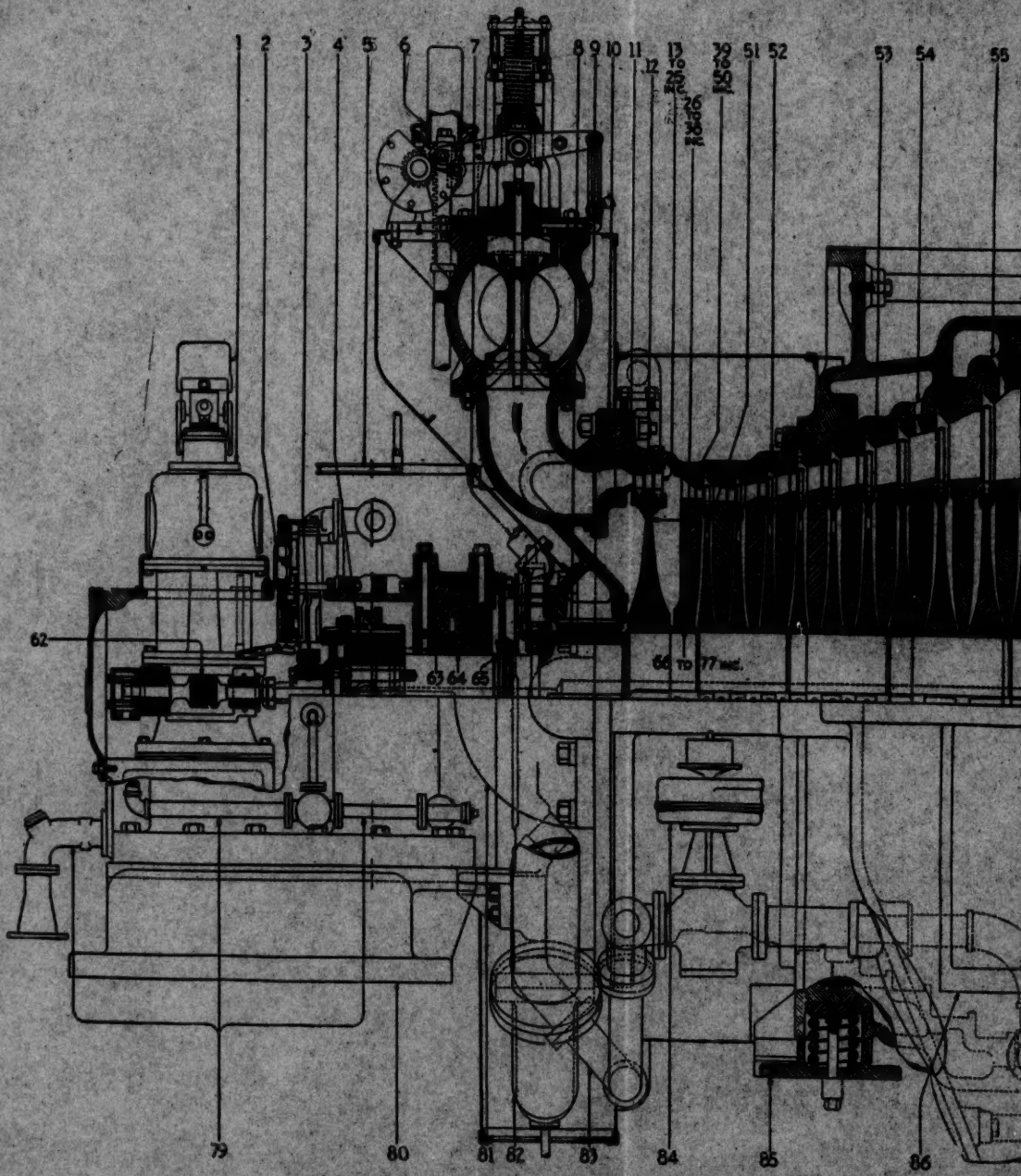
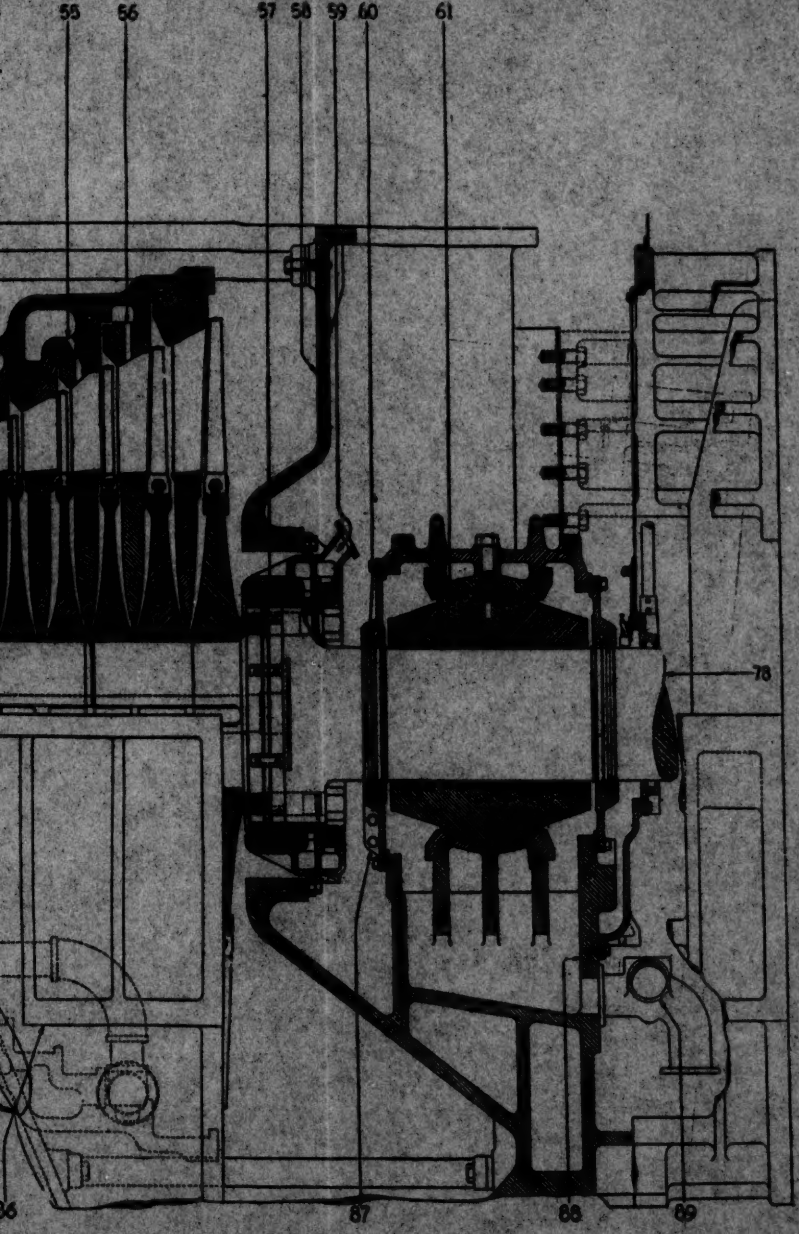


FIGURE 3.—MAIN



RE 3.—MAIN TURBINE ASSEMBLY.

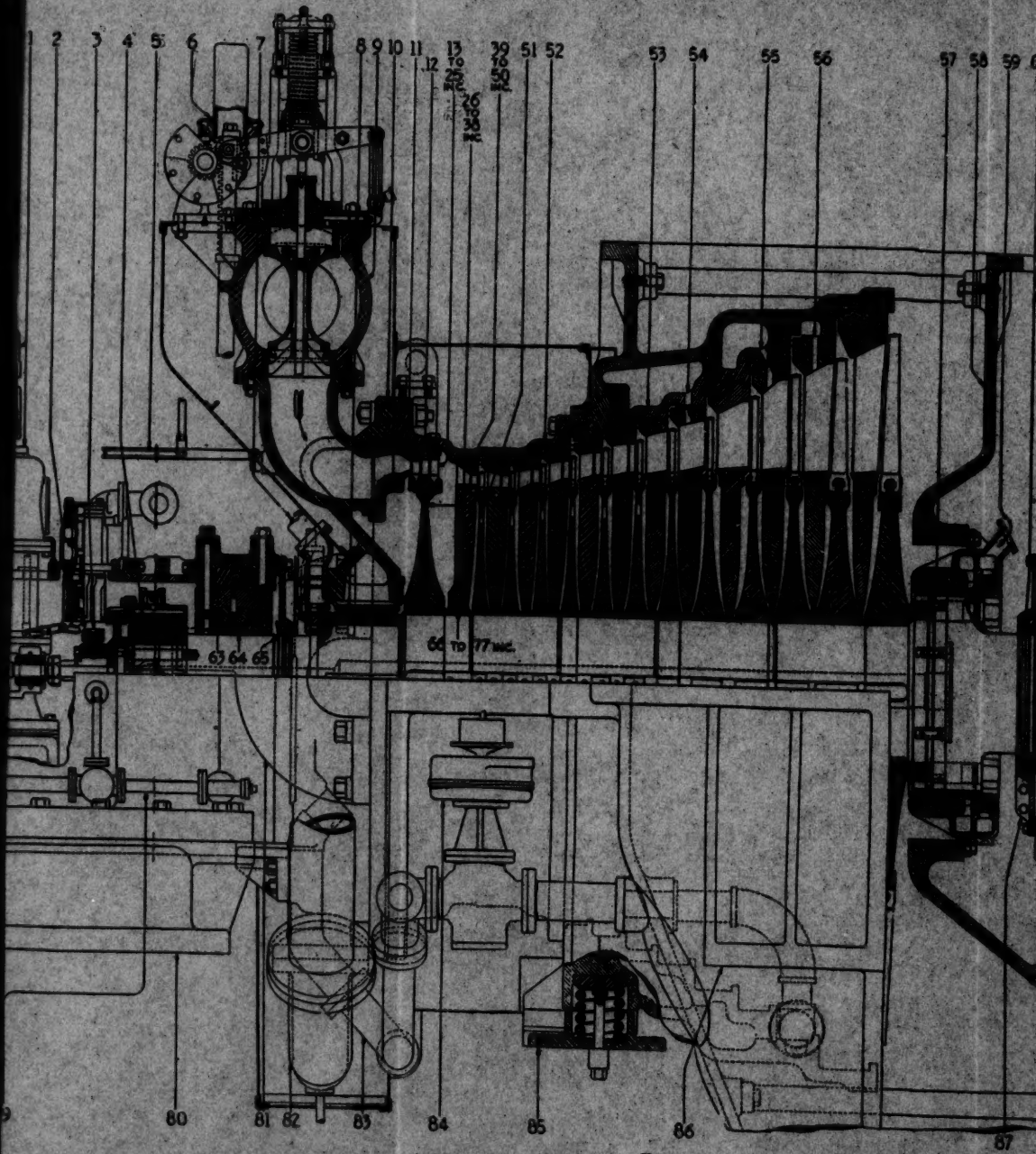
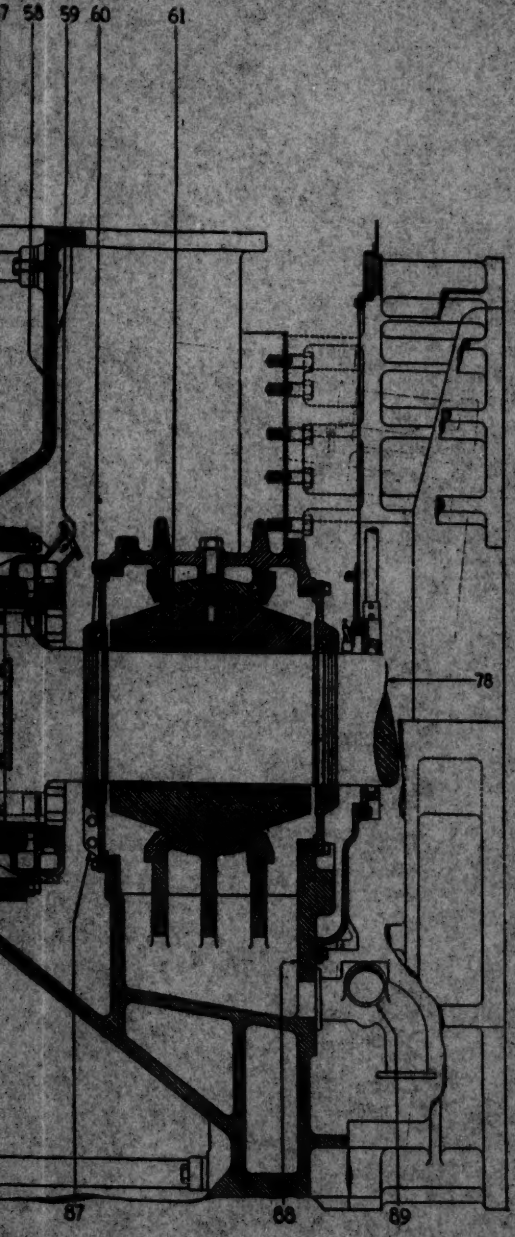
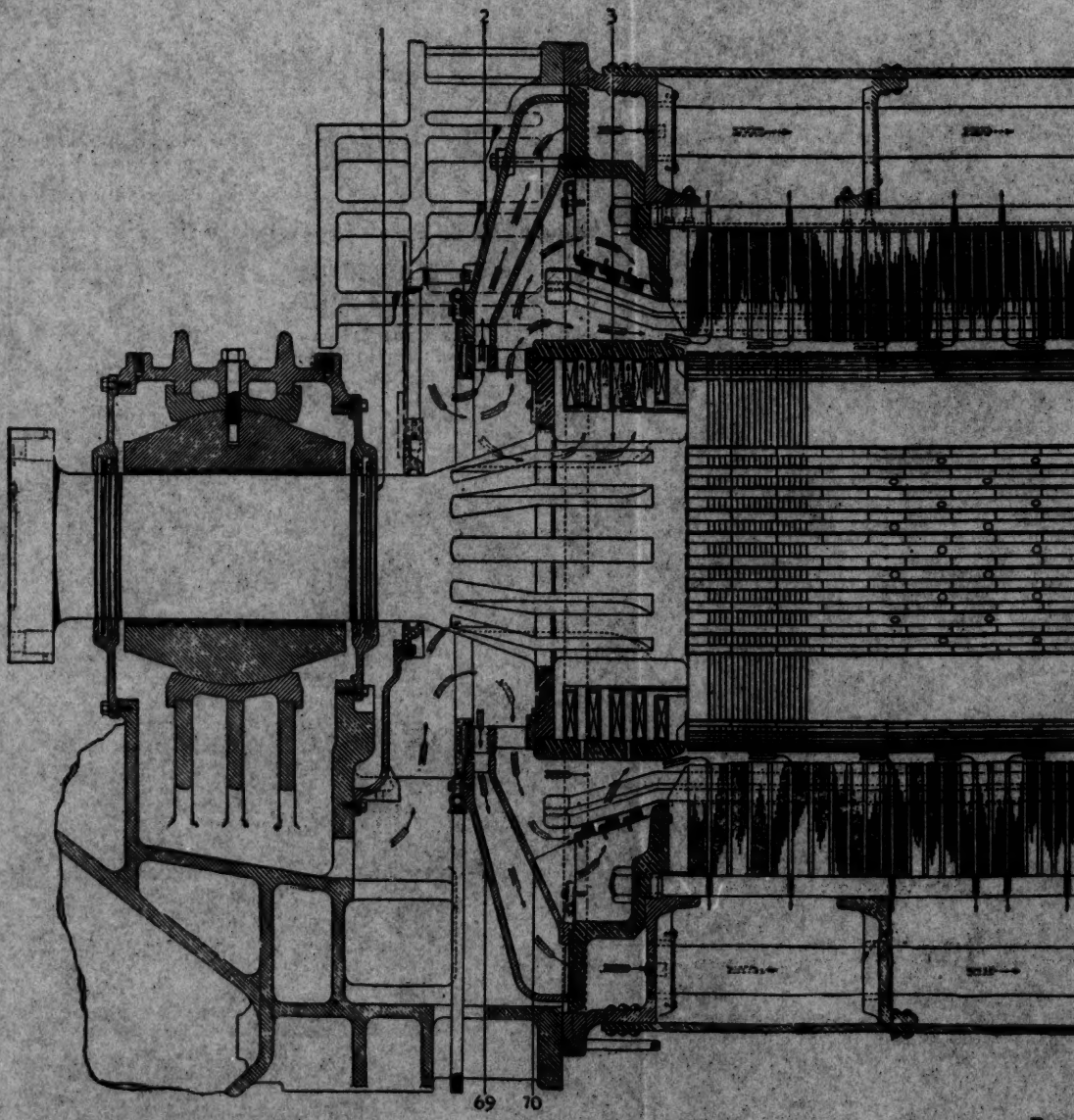


FIGURE 8.—MAIN TURBINE ASSEMBLY.



LEGEND FOR FIG. 1

1 Operating Governor
2 Pilot and Oil Release Valves
3 Emergency Governor
4 Thrust-bearing Assembly
5 Connecting Rod to Steam Inlet and Hydraulic Gear
6 Rack and Pinion Assembly of Hydraulic Gear
7 Connection to Vapor Suction System
8 High-pressure Packing Assembly
9 Controlling-valve Assembly
10 Turbine Head
11 First-stage Nozzle
12 Intermediate Segment with Stationary Buckets
13 to 25 Incl. Buckets
26 to 30 Incl. Bucket Wheels
31 to 36 Incl. Nozzle Diaphragms
41 Equalizing Holes
42 Turbine Shell
43 Turbine Inner Shell
44 Auxiliary Exhaust Steam Inlet to 8th Stage
45 Auxiliary Exhaust Steam Inlet to 10th Stage
46 Inlet to 11th Stage from Unloading Valve
47 Low-pressure Packing Assembly
48 Exhaust Hood (Upper Half)
49 Discharge to Condenser
50 Oil-deflector Fan
51 Turbine Middle Bearing
52 Governor-drive Worm Gear
53 Adjusting Nut
54 Turbine-end Bearing
55 Oil-deflector Fan
56 to 77 Incl. Diaphragm Packing
78 Generator Shaft
79 Oil Piping
80 Base
81 Turbine-end Support
82 Steam Piping
83 Piping for Steam Sealing
84 Unloading Valve
85 Spring-box Support
86 Exhaust Hood (Lower Half Turbine End)
87 Oil-deflector Assembly
88 Exhaust Hood (Lower Half Generator End)
89 Illuminated-sight Oil Discharge



FIGU

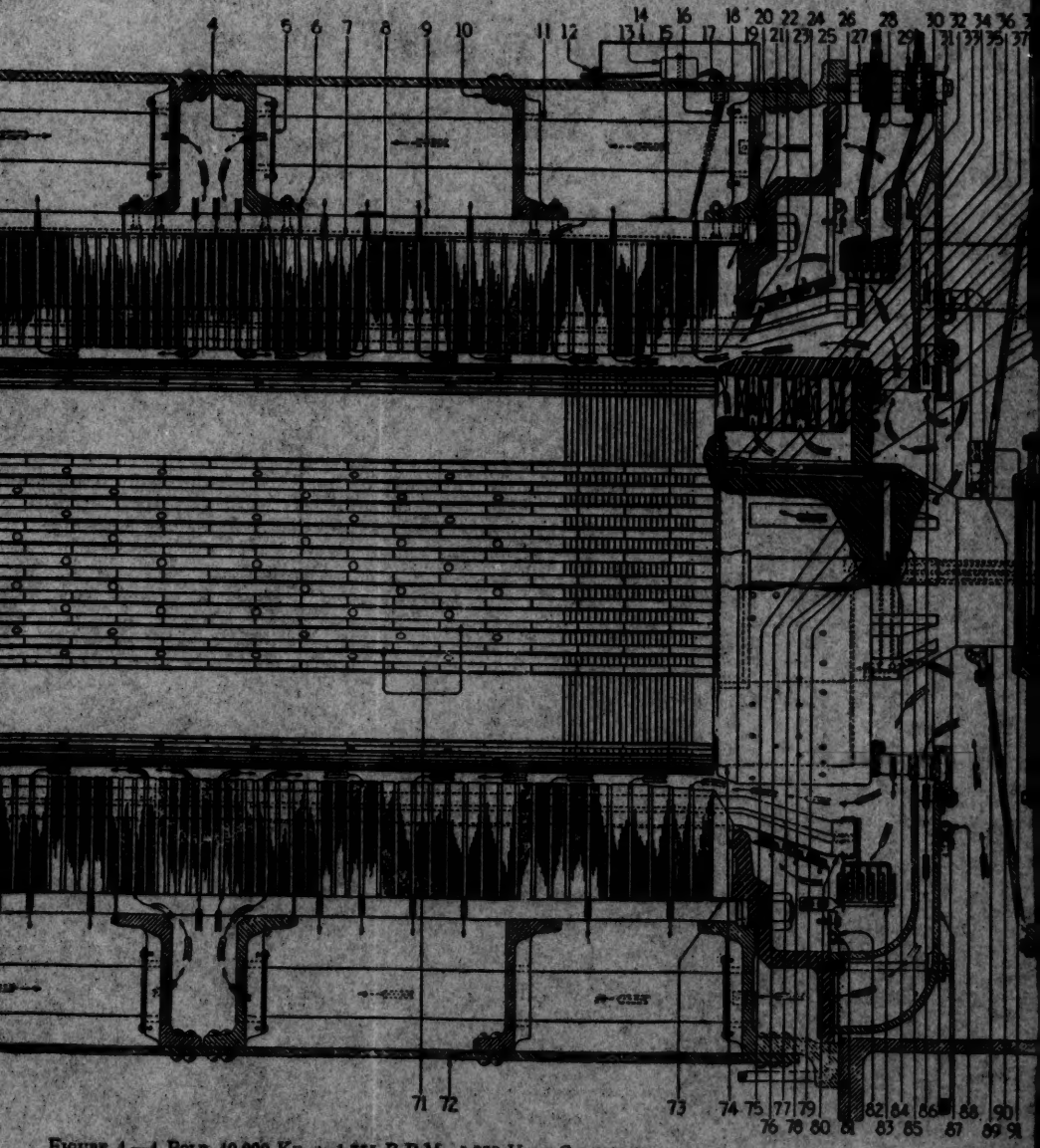


FIGURE 4.—4 POLE, 40,000 KV.-A, 1,755 R.P.M., 5,000 VOLT GENERATOR.

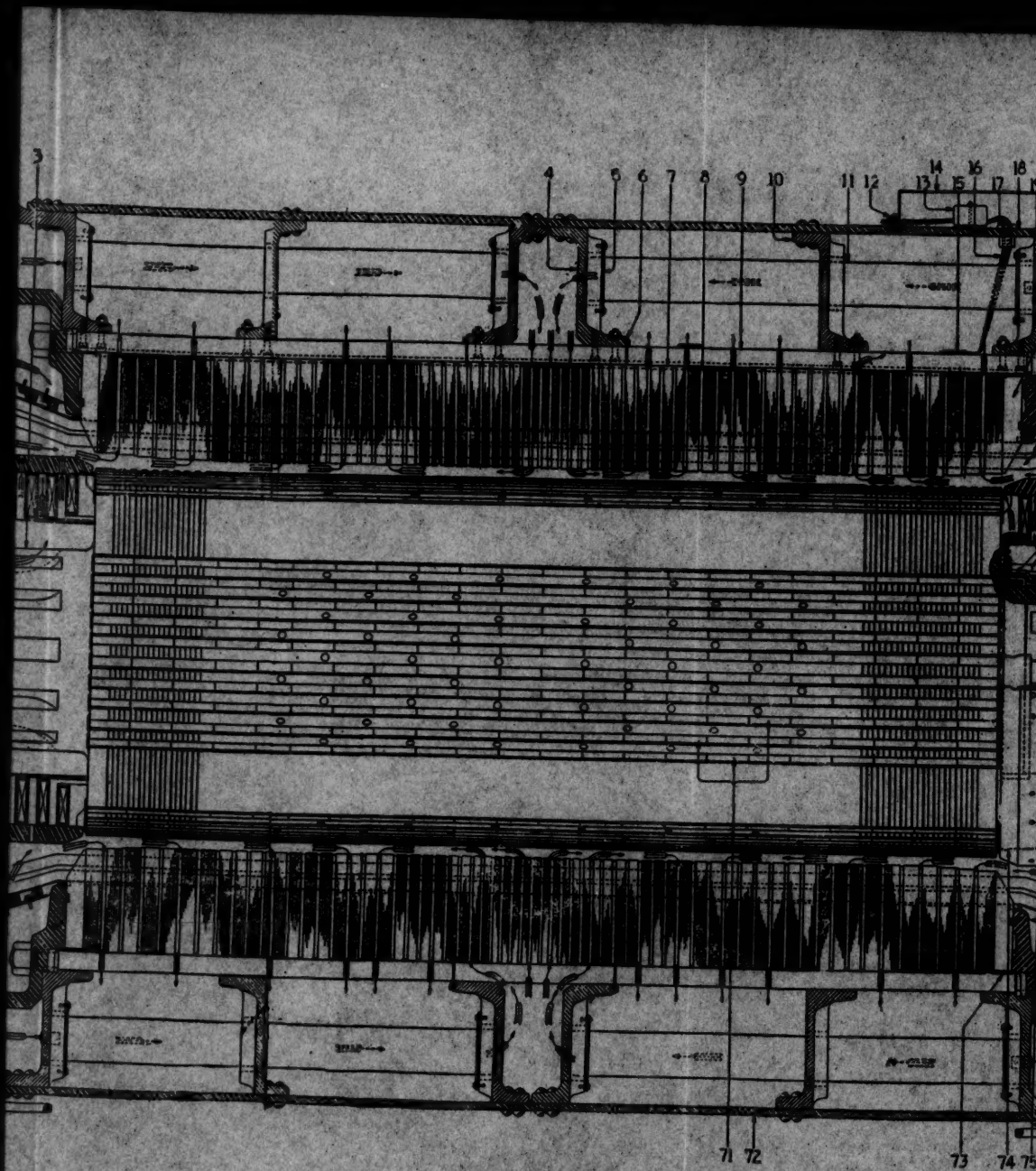
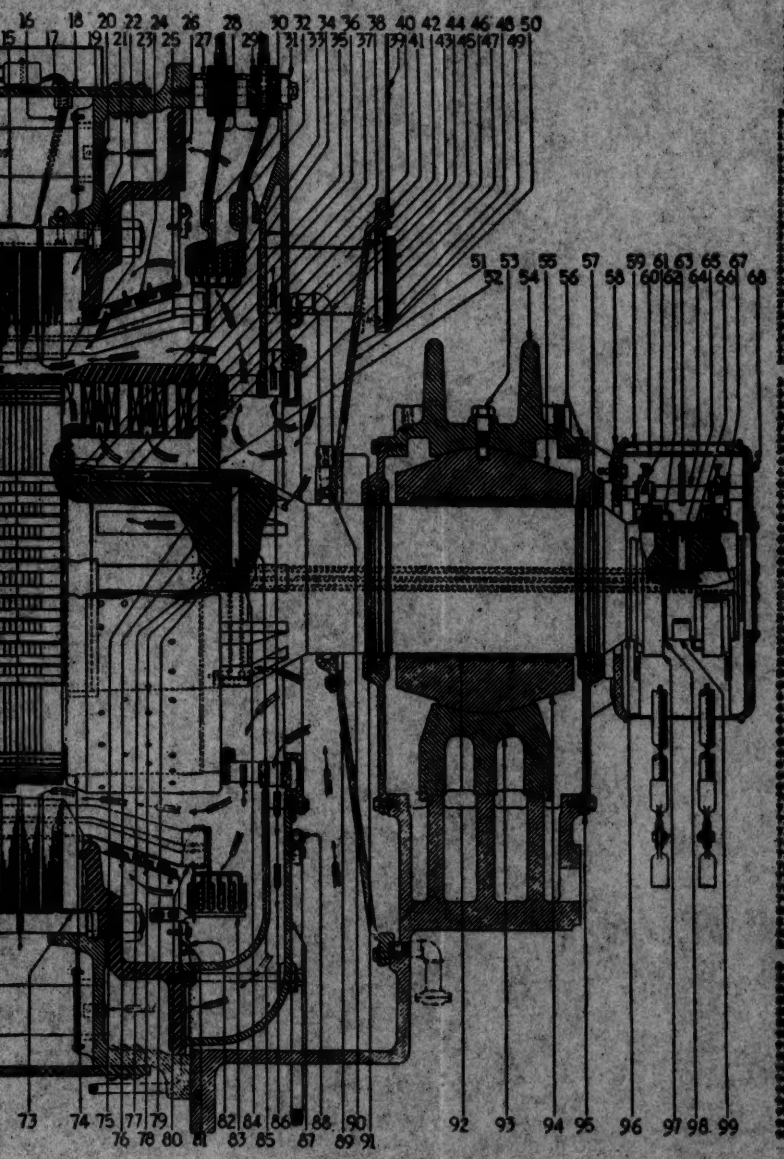
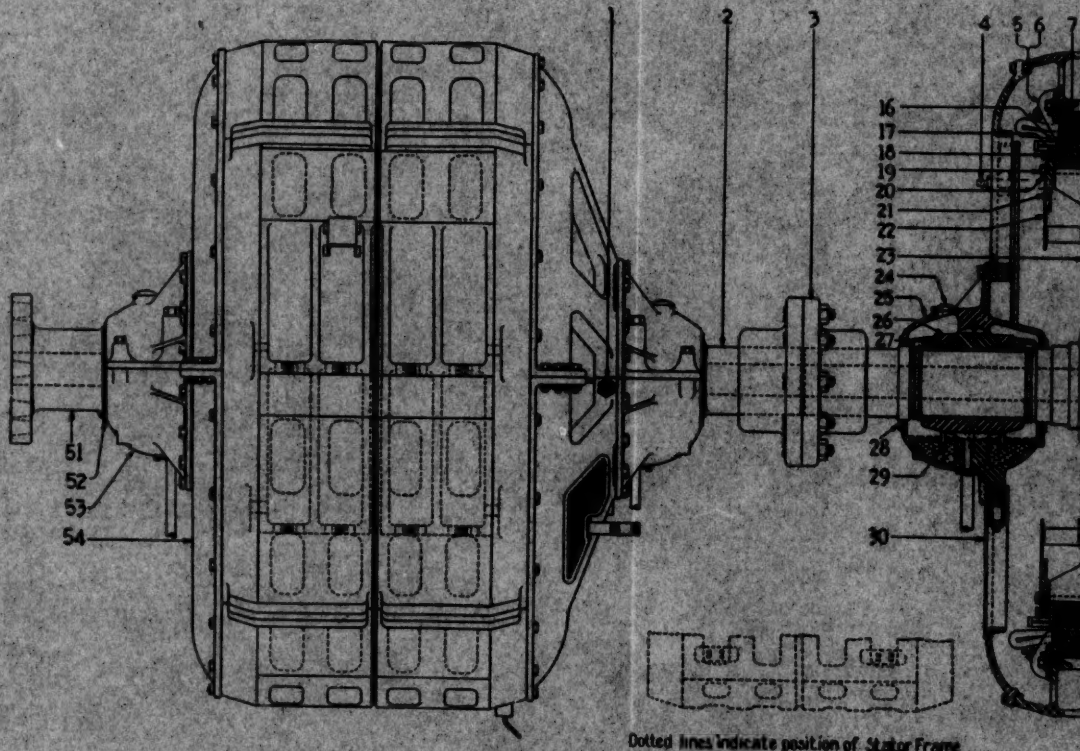


FIGURE 4.—4 POLE, 40,000 KV.-A, 1,755 R.P.M., 5,000 VOLT GENERATOR.





Dotted lines indicate position of Stator Frame when clear of Rotor to permit repairs

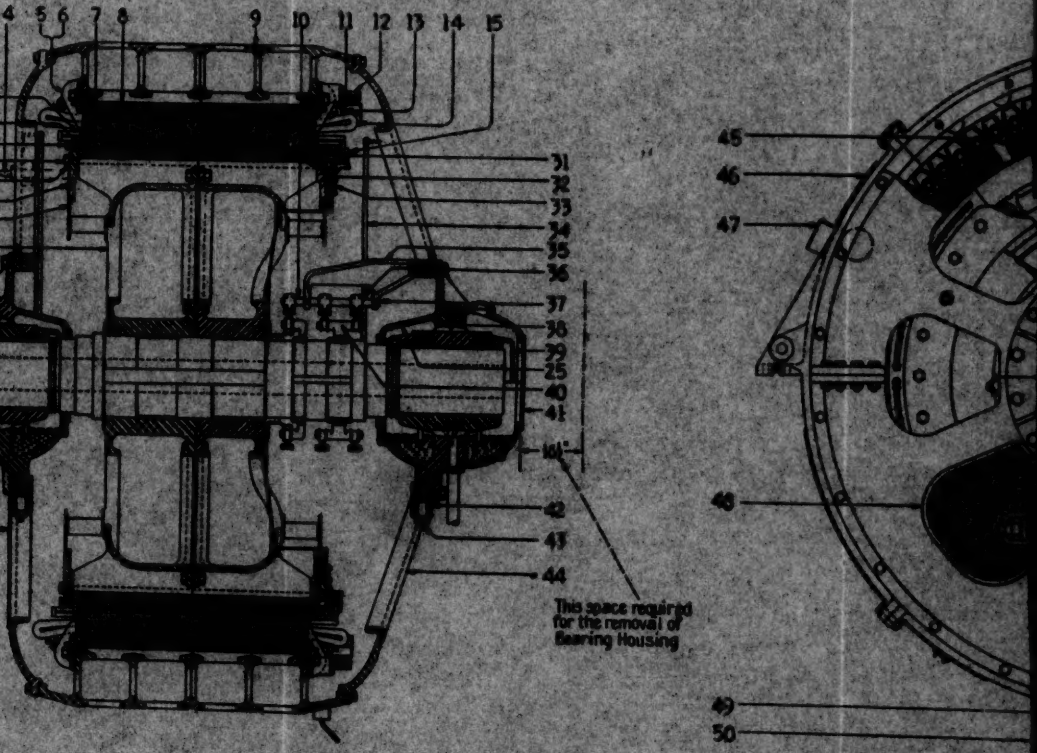


FIGURE 8.—ASSEMBLY OF PROPULSION INDUCTION MOTOR.

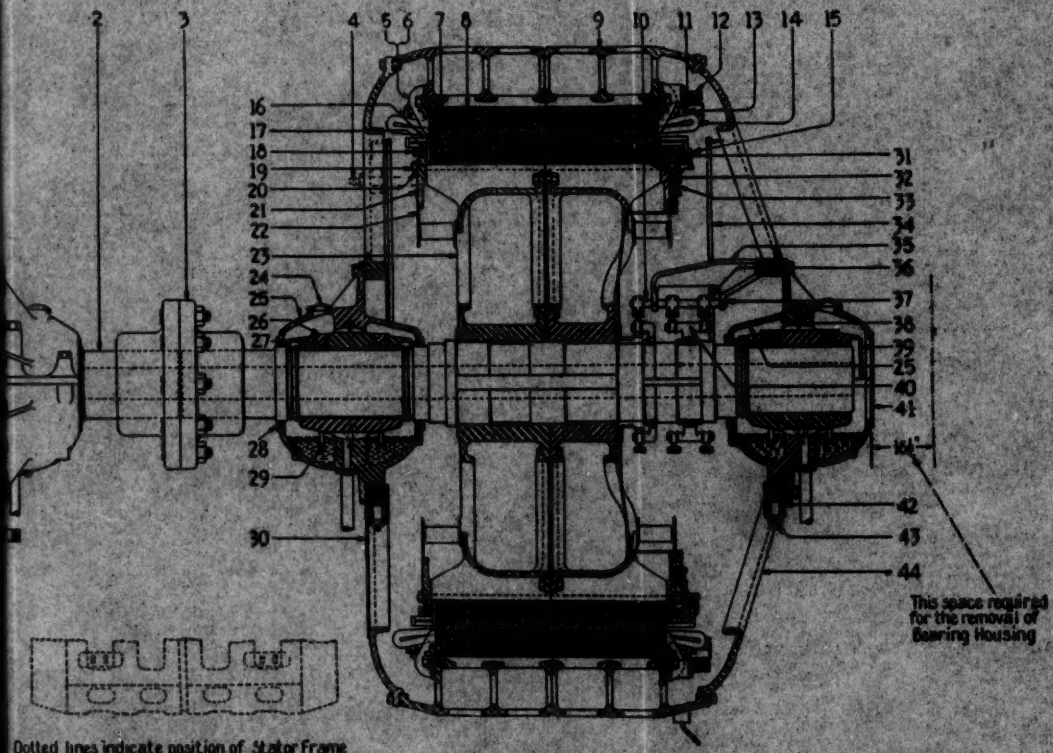
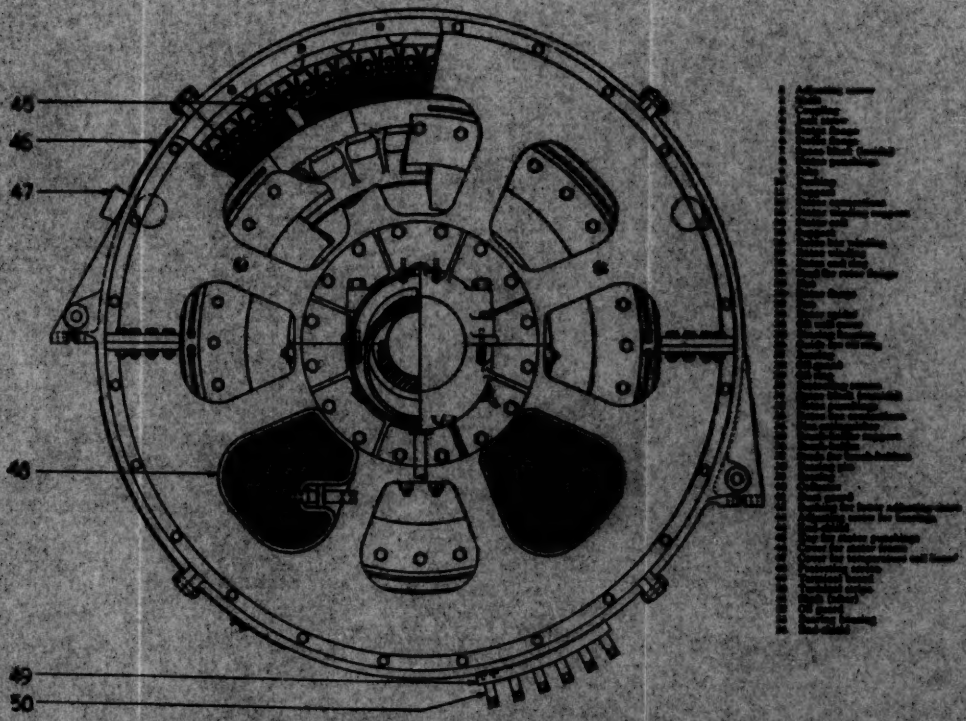


FIGURE 5.—ASSEMBLY OF PROPULSION INDUCTION MOTOR.


45
46
47
48
49
50

the piston rod of a hydraulic cylinder. The piston of the hydraulic cylinder is moved by oil under pressure. The pressure of the oil is regulated by a pilot valve which is in turn operated by a link mechanism driven by the operating governor which functions with changes of turbine speed. The governor is of the variable setting type, and variations in setting are effected by one of two ¼ H.P. electric pilot motors mounted in pairs, one pair on the governor, and the other on the steam limit switch. The pilot motors are operated from the main control room.

Other features are:

An emergency over speed governor, arranged for test tripping by means of lubricating oil under pressure.

Steam packed glands with unloading valve to low pressure stage.

Self aligning, spherical seated, pressure lubricated bearings.

Adjustable thrust bearing.

Single row of buckets for all wheels, except first stage wheel which has a double row with intermediate segment carrying fixed buckets.

Auxiliary steam connection admitting auxiliary exhaust steam via constant back pressure valve and hydraulically controlled admission valve to either the 8th or 10th stage of the turbine as desired.

The turbine is directly coupled with the alternator by a solid flanged coupling.

CLASS S41-4 — MAIN PROPULSION MACHINERY — TURBO-ELECTRIC DRIVE, MAIN ALTERNATORS.

The main alternators are four in number and are shown in cross section, Figure 4. Each alternator is rated as follows: 40,000 KV.A., 1755 R.P.M., four poles, three phase, 5000 volts. Supplied by the General Electric Company.

In general, the alternators consist of a stator or armature, a rotor or revolving field, end shields, collector, brush holder rigging, a self-contained water cooled ventilating system, and a hand operated jacking gear.

The stator frame is of the built up type consisting of annular castings with large supporting plates riveted to their outer periph-

ery and rectangular shaped ribs bolted longitudinally to their inner periphery. The ribs support the core laminations which are held in high compression by the end flanges. The whole is surrounded by a sheet steel casing to provide means for containing and directing the air of the enclosed ventilating system. The core is made up of stacked annealed, insulated, iron laminations with air ducts for the ventilating air and open slots for receiving the coil bar windings. The stator winding consists of 192 coil bars, each of which is made up of rectangular, insulated, copper strands connected in multiple. Treated wooden wedges hold the coil bars in the core slats. The pole connections are made to a series of rectangular copper bars formed circular around the outer periphery of the winding. The insulation consists of five layers of tightly wrapped mica tape, wound half lap, applied with insulating varnish sticker. Two layers of linen tape are wrapped over the mica and then given five coatings of varnish baked after each application.

The rotor consists of a shaft, body, windings, collector rings, and a centrifugal fan for air circulation. The shaft and rotor body is a solid forging with slots milled in the latter for the windings. Ventilating channels communicate with holes bored through the teeth at intervals along the core body. The collector ring leads are brought in via a longitudinal hole through the middle of the shaft and thus reach the rotor windings. The rotor winding consists of five coils per pole and are made up from copper strips wound edgewise. The coils are insulated and protected from the core by a combination armor of asbestos cloth and mica sheets. The coils themselves are insulated with mica tape pasted with shellac. Mica and asbestos tape is wrapped around the end projections beyond the core. The end turns are fitted with aluminum saddles and are blocked with alloy spacers to hold windings in place. Nickel steel retaining rings with holes for ventilation are placed over the coil ends and shrunk on to steel centering spiders placed outside the windings. There is a centrifugal ventilating fan at each end of the rotor body; these are of the double bladed type. The collector is a separate part made up of two forged steel rings shrunk onto the mica covered cast iron shell. The latter is bored to a drive fit on the shaft. Copper studs and bars make connec-

tion between the collector rings and the field windings via the hollow shaft. The brushes consist of an assembly of fifty-four self-lubricating graphite brushes.

The ventilating system is enclosed to insure delivery of clean air. The rotor fans force the air stream around the ends of the stator windings into air gap, also via the stator core. From the air gap air is forced outboard through numerous ducts in stator core to the exterior of the generator proper where it enters water cooled air coolers of the fin tube type. After passing the coolers the same air is withdrawn by the fans and recirculated once more, the whole cycle being repeated about seventy times per minute, so that about 80,000 cubic feet of air per minute is thus handled by the fans. The air coolers are kept cold by sea water which is forced through the inside of the fin tubes by either a pressure or a vacuum system, both of which are supplied and can be used at will, although the latter is the standard for ordinary usage.

Each alternator is supplied with steam heating coils for standby conditions, and perforated steam coils are installed for the admission of steam for fire extinguishing purposes in emergency.

MAIN MOTORS.

The main propulsion motors are eight in number, two per propeller shaft in tandem, and are shown in Figure 5. Each motor is rated as follows: Three phase, 22 or 44 pole, 22,500 or 5500 H.P., 317 or 162 R.P.M., 5000 or 4900 volts, induction type. Supplied by General Electric Company.

The motor stator is cast in eight sections, machined and bolted together. The stator core is built up from sheet steel punchings 14 mils thick, enameled on both sides to reduce eddy currents. Each layer of punchings overlaps the next layer by half a segment and is held in place by dovetail keys securely fastened to ribs of the stator frame. The core is assembled with space blocks spot welded to the adjacent punchings and inserted radially around the core at intervals. The ventilating air flows through the core to the frame and out to the separate ventilating fans. The stator windings are 396 in number and are made up of eight turns of rectangular wire enameled and then covered with extra heavy cotton covering im-

pregnated with varnish. The coils are moulded and formed accurately to shape. Insulation is placed between turns in the slots and the end of each turn is taped to avoid short circuiting turns.

Each coil is then insulated with four layers of mica tape wound half lap, followed by windings of linen tape, the latter treated with several treatments of moisture resisting varnish. The coils are baked and inserted in the slots and held in place by bakelite-canvas wedges driven into notches provided in the stator teeth. Maple wood blocks are inserted between coils on the ends, held in position by tying to adjacent coils which are also laced rigidly to steel supporting rings. Connections are brought out to insulated bus rings, and the motor terminals from these rings are carried down through the frame and held in place by a connection board at the bottom of the stator frame casting. The windings are so grouped that the six terminals provide for multiple and series connections suitable for the 22 and 44 pole operation respectively.

The rotor consists of two cast steel spiders bolted together and keyed to the shaft. The core, similar to that of the stator, is assembled on the rotor spider. The punchings are held together between continuous steel rings clamped by through studs passing via the spider. The rotor carries fans which direct the air flow, thus acting in an auxiliary capacity to the independent ventilating fans. The rotor is equipped with two independent windings in the same slots. In the bottom of the slots are tight fitting bars of high resistance material, (25 times resistance of the low resistance winding material). These high resistance windings are brazed at each end into the segments of the sectionalized squirrel cage end rings. The segments are connected by laminated, flexible copper strip thus providing against expansion strains. The bars are extended beyond the end rings to provide support for the outer windings. The low resistance windings are placed in the outside of the slots and consist of insulated bars of phase windings. Thermal insulation is provided by strips of bakelite-asbestos between the windings. The phase wound coils of each turn consist of solid copper bars insulated with four layers of one-half lapped mica tape covered with linen tape and several layers of varnish. The bars are formed at one end, the other end being formed after assembly. The bars

are connected in groups by soldered clips which are connected together by phase belt connections of involute form, the latter being supported against centrifugal force by steel brackets. These provide circuits which render the phase windings responsive to either 22 or 44 pole distribution in the stator. In the case of 22 pole distribution, the circuits are completely closed and form short circuits for all induced secondary currents. In the case of the 44 pole distribution the series circuits formed can only be closed by short circuiting the slip rings on the end of the rotor to which they are connected at various tapping points. When closed, the secondary winding permits a 6 phase system of currents to flow. The slip ring connections are externally short circuited by a rotor switch operated by air pressure from the control room, or by hand lever from the motor room.

VENTILATION SYSTEM — MAIN MOTORS.

The ventilation system of the main propulsion motors consists essentially of circulating fans on the main motor rotors, independent motor driven blowers, and water cooled air coolers. The system is semi-enclosed as compared to that of the main alternators; that is to say, the motor room itself forms a part of the circulating system. Supplied by General Electric Co.

There are four independent motor driven fans for each pair of main motors in each motor room, two fans per motor; these four fans are driven by three motors. The arrangement is such that the two fans located between the pair of main motors are driven by a single motor, while the two outer fans are each operated by an independent motor. The fan motors are operated from the same power supply as the main propulsion motors. The supply being at a maximum potential of 5000 volts A. C. The construction of the motors is therefore similar to that of the propulsion motors. The fan motors are connected by independent cut-out switches in the control room, but when switched in are controlled with the main motors. Blowers are supplied by Sturtevant Co., and each fan is rated at 42,500 cubic feet per minute. The motors are induction type, 8 pole, 3 phase and are 125 H.P. for single and 250 H.P. for double fans, at 875 R.P.M.

The scheme of ventilation is so carried out that air is drawn into the propulsion motors by means of the main motor rotor fans and drawn through the main motor interiors by suction of the motor driven fans, the latter being connected by ducts to the main motor stators. The discharge from the motor driven fans is back to the motor room via the fin-tube water cooled air coolers. The air is then again drawn from the motors room for re-circulation.

The air coolers are designed for the maximum rating of the motors with circulating water at 90 degrees F.

EXCITERS.

The regular 750 Kw. ship's service turbo-generators are used for excitation of the main alternators. These are described more fully under Class S61. Supplied by General Electric Co.

BOOSTERS AND EMERGENCY FEED RHEOSTATS.

Inasmuch as the output of the 750 Kw. ship's service turbo-generators is also utilized for ship's power at constant voltage of 240 D. C., the use of some means for variation of this voltage for the excitation of the main alternators is essential. This means consists of four motor-generator booster sets, one mounted on top of each of the main alternators with which it is normally used. There are also two emergency rheostats in the control room for use in emergency if the motor-generator boosters fail. The use of the boosters may be interchanged on each pair of main alternators in the same machinery space. One emergency rheostat can be used on either of two main alternators, one in each machinery space, and the other rheostat may be used on either of the remaining two. These are all supplied by General Electric Co. Motor end is compound wound, 240 volts, 175 ampères, 50 H.P., 975 to 1425 R.P.M. Generator end has two differential shunt windings, full "buck," to 200 volts, full "boost" to 280 volts, main shunt field is separately excited from 240-volt source.

CONTROL GEAR.

Propulsion control is effected via a system of contactors, operating and controlling mechanisms, necessary indicating instruments, interlocks, etc., grouped in an independent control room

located aft of the main machinery spaces, and forward of the main motor rooms. The general arrangement of port contactor groups is shown by Figure 6. The layout of the indicating instruments and operating levers is shown by Figure 7. The outfit may be considered as divided into two general parts by an athwartship partition; the forward portion contains the actual switches and switch operating mechanism, while the after portion contains the control board on which are mounted the indicating equipment and the control levers and gear. The switching equipment consists of a number of controllers arranged in starboard and port sections each consisting of two divisions; each division is in turn arranged in three groups, one above the other, see Figure 6. The bus bars are mounted in double layers above the contactor groups. Necessary barriers are disposed in such a manner as to prevent cross currents of air which might cause trouble in case of short circuits.

The main control contactors are closed and opened by means of cam shafts extending the whole length of each group. The cam shafts are driven by compressed air engines controlled by air valve levers on the control board. In addition, a manual operating equipment is provided for use in case of failure of the pneumatic system. The reversing and fan motor group control is of special interest in that the contactor groups serve a triple purpose, viz: Main disconnecting switches, reversing switches, and motor cut-out switches. The first two are operated by air engines which are controlled by two levers on the control board, one for starboard groups and one for port groups. The main motor and fan cut-outs are controlled by manually operated levers arranged for disengaging or engaging the reversing and fan motor contactors whenever it is desired to cut out or in a particular fan or main motor; these levers, however, cannot be operated unless the contactors are in the open position. The pole changing contactors are operated by their respective air engines to establish either the 44 or 22 pole connections of the main motors and the air engines are operated by the same air valve levers that handle the reversing groups.

Refer to Figures 1 and 2 for general generator and motor combinations and switching arrangement. The switching combinations of the generators are made effective by manipulation of a

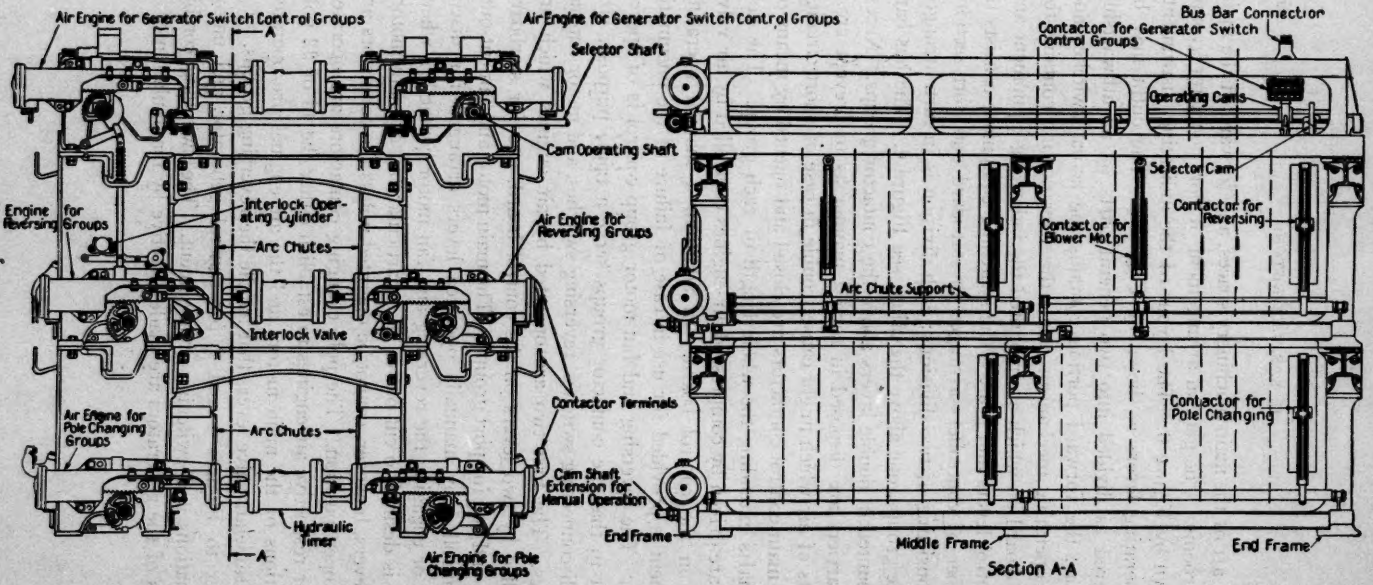


FIGURE 6.—ARRANGEMENT OF PORT CONTACTOR GROUPS AND AIR ENGINES.

STEAM CHEST TURBINE A
MAIN STEAM FORWARD
STEAM CHEST TURBINE B
MAIN CONDENSER TURBINE A
MAIN CONDENSER TURBINE B

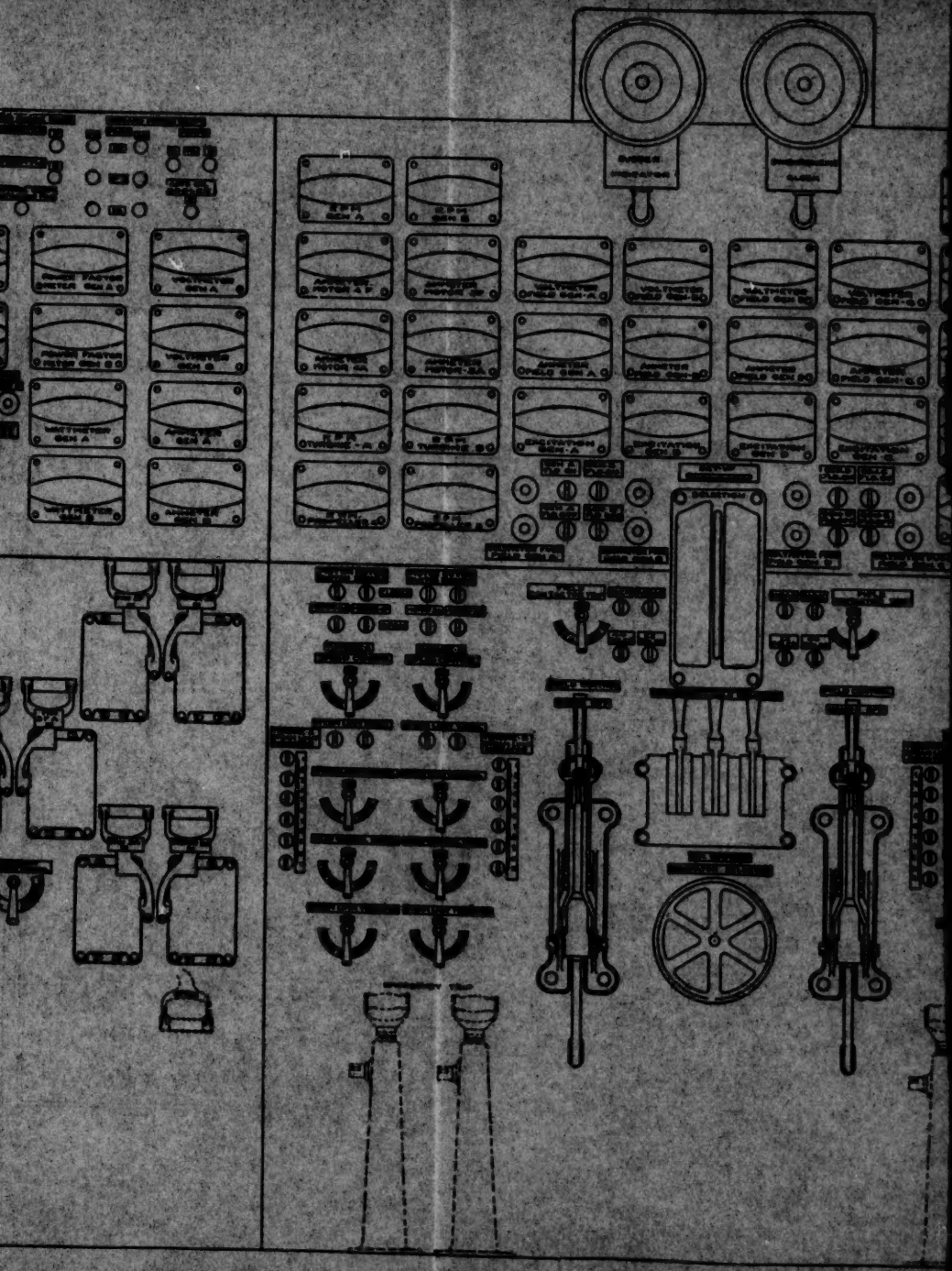


FIGURE 7.—MAIN CONTROL PANEL.

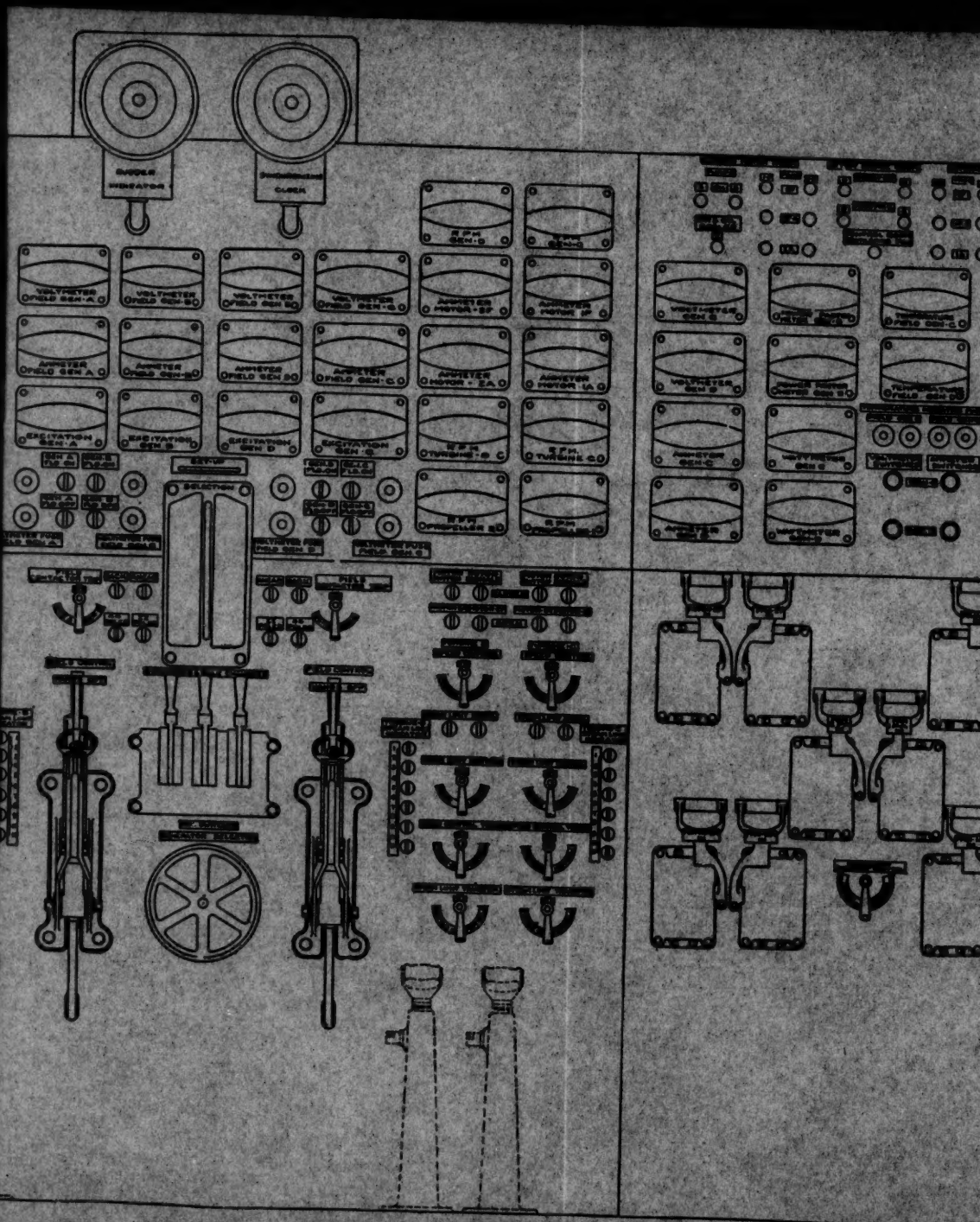


FIGURE 7.—MAIN CONTROL PANEL.

selector mechanism; the selector indicator and controlling hand wheel are mounted on the front of the control panel. By rotating the hand wheel, a selector shaft is turned through a gear train which mechanically selects the particular generator switches that must be used in the combination selected. Thus when the selector has been operated and a given set-up made the air valve control levers are manipulated in the proper sequence for switching; interlocks prevent improper sequence. In accordance with the manipulation of the levers, air is admitted to, or exhausted from the air cylinders and the pistons function to rotate the cam shafts by means of racks and gears, thus closing or opening controllers required by the selector set-up. The piston rods of the air cylinders pass through hydraulic timing cylinders fitted with pistons which are located midway between the end frames of the contactor sections. In the case of the air cylinders for the generator control groups, the hydraulic timer serves merely as a dashpot at the end of the throw of the air pistons. However, for the reversing and pole changing air cylinders, the hydraulic timer serves both as a dashpot and a timer. The timer controls the movement of the air pistons by means of ports through which the contained fluid can be by-passed, and the operation is such that as air is admitted and the piston begins to move, the operation will be at first slow and later will change to a comparatively rapid movement as the contactors start to open. The general requirement for the first feature is to provide that sufficient time may elapse to permit the current to die down to a low value before the main contactors open. In order to insure that no current is broken on the generator switches, interlocks insure that the reversing control groups must be thrown to the "off" position, and all circuits leading from the generator switches thus opened before the latter can be moved.

The generator field contactors together with the booster field rheostats comprise the field control for the alternators. Two field contactors carry the current of each turbo-alternator. The contactors are each equipped with magnetic blowout and two sets of contacts operating in the blowout field; one set of contacts establishes the excitation circuit, and the other connects a discharge resistor across the alternator field. The contactors are closed by an operating cam and shaft moved manually by a field control lever

mounted on the front of the control board. There is an auxiliary method of tripping open the field contactors by means of a separate tripping lever also mounted on control board, and this same trip is also operated by the various protective relays. There is one field control lever for each pair of main turbo-alternators, so that, with all four operating, one lever controls the fields of both alternators handling the starboard motors, and one the alternators handling the port motors. The booster field rheostats are combined in one frame and connected to dial switches operated by means of a double rack attached to the operating mechanism of the field controller. Thus when the field lever is operated to pull on the field the field contactors are first closed and further movement of the levers turns the booster field rheostat increasing the strength of the alternator field; further advance of lever means still more field until full field and then super-excitation is applied. As the motors pull into step the field lever is moved backward reducing super-excitation, closing the motor rotor switches by air, and finally reaching full field where a vernier attachment permits fine regulations of the field rheostat to bring excitation to the strength desired. A red lamp located directly over levers shows when field contactors close and a green lamp shows when they are open. In returning to the "off" position the field lever operates an air valve which opens the motor rotor switches; the operation of the motor rotor switches is also shown by signal lamps.

Interlocking between the field levers and control gear is such that the operation of the control groups is impossible unless their corresponding field levers are in the "off" position.

In general, the main contactors of the control groups are of the magnetic blowout type. The contact making parts are surrounded by an arc chute of asbestos compound which is equipped with a powerful magnetic blowout feature. The magnetic field of the blowout is set up by one solenoid shunted (in series in case of some contactors) with the circuit which passes through the current carrying parts, and by two other solenoids which increase the strength of the magnetic field after the contacts have opened. When the contacts open the magnetic field set up by the blowout coils causes an arc to move from the contact tips to arcing horns

which are in circuit with the second set of blowout coils. Thus as the arc is stretched the magnetic field is intensified and the arc is moved more rapidly to the rupture point. As the arc moves along the cool metal of the arcing horns the amount of ionized conducting air is reduced. The shape of the horns is such as to stretch the arc out and draw it away from the restricted part of the arc chute near the contacts. The asbestos arc chute is split so as to increase the creepage distance between the main contacts when switch is open.

The main motor rotor switches are located near the respective motors served by each switch in the motor rooms. These switches are operated by air and controlled in the control room by movement of the alternator field lever. They can also be operated manually in the motor rooms by hand levers. Signal lights show in control room and in motor rooms the operation of the switches. An air pressure gauge is mounted near the station of the man on watch in the motor room by which failure of air pressure can be at once made known to the operator of the manual lever.

In general the control board carriers the operating levers and all indicating instruments both for electrical quantities and pressure and temperature indicators. The following equipment of the control board is briefly described:

GENERATOR SWITCH LEVER.

Has three effective positions, viz: "open," "run" or "set-up," and "close." The interlocking is so arranged that the switch is inoperative in the "run" position except when the reversing and pole changing levers are in the "stop" position. Also it is locked in the "run" position when the contactor groups are operated by the manual operating mechanism. The lever is further locked so that it cannot be moved from the "open" or "close" position while the generator contactor camshafts are moving between the "open" and "close" positions.

REVERSING AND POLE CHANGING CONTROL LEVERS.

These have four effective positions which are arranged outboard from the control panel in the order, "22 poles" and "44 poles" (ahead), "stop" and "44 poles" (astern). The interlocking provides the following:

(*a*) Starboard and port levers are inoperative when corresponding field levers are "on."

(*b*) Both levers are inoperative when a single field lever is in use for operating both sides of the ship, provided either field lever is "on."

(*c*) Both levers are inoperative in the "stop" position when the generator switch lever is in either the "open" or "close" position.

(*d*) Both levers are inoperative when the groups are being operated by the manual control.

Purple indicating lamps are used to give indication of the operation of these control groups; the lamps are lighted when the contactor groups have completely functioned.

MOTOR CUTOUT LEVERS.

Main motor and ventilating fan cut-out levers are marked with the designation of the motor controlled and are used to arrange the contactors of the control groups with respect to their operating shafts so that only those desired will be effective during a switching operation. The interlocking of these levers is such that change or selection of reversing or fan motor contactors is impossible except when the operating shafts of the reversing and fan motor groups are in the mid-position.

TURBINE SPEED, STEAM LIMIT, EMERGENCY TURBINE TRIPS, ETC.

The control handles on the control board are connected electrically to the governor speed and steam limit motors in the machinery spaces. There are two speeds possible through two positions of the turbine speed lever in varying the turbine speed, one for fine adjustment and the other for quick change in maneuvering. Separate switch levers permit the selection of either one of the pair of motors on each governor for either speed change or steam limit.

There are two signal lamps above each steam limit handle which show the relative position of the limit stop and the governor mechanism when the latter approaches the stop. At the side of each steam limit control handle are six indicating lamps in a vertical row which show the actual setting of the steam limit mechanism.

Emergency trip handles are located on the operating platform in front of the control panel for manual tripping of the main turbine throttle valves from the control room in emergency.

PROTECTIVE RELAYS.

A duplex system of protective relays is connected into the field circuits of each main alternator for the purpose of protecting the power circuit from serious damage from grounds or unbalanced phases. The effect of the operation of these relays is to trip out the field contactor of the alternator concerned in the ground or unbalance. These relays are operated on the secondary of current transformers suitably located. In the case of the ground relay the current transformer is located on the grounded neutral of the alternator. The unbalance relay transformer is in the alternator field circuit; it is so constructed as to have a small resistance to the flow of the direct current normally required for excitation, but in case of unbalanced phases in the alternator the double frequency oscillations set up in the field circuit induces a current in the transformer secondary which passes through the relay and causes it to function to trip the alternator field. This relay is set to function normally at 50 per cent unbalance.

There are suitable special circuits installed to permit testing of ground and unbalance relays to insure that they will operate satisfactorily. Special testing transformers are installed for this purpose.

INDICATING INSTRUMENTS.

The following is a general list of the instruments installed on the control board:

Steam pressure and air pressure gauges.
Vacuum gauges.
Feed pressure gauges.
Fuel oil pressure gauges.
Auxiliary exhaust gauges.

The above are mounted on wings at either side of the control board proper, see Figure 7.

D. C. ammeters and voltmeters — field circuits.

A. C. ammeters and voltmeters — main generators and motor circuits.

Wattmeters — main propulsion circuits.

Power factor meters — main propulsion circuits.

Frequency and speed indicators — main alternators.

Speed indicators — main motors and alternators.

Temperature indicators — main alternator fields.

Embedded detector temperature indicators — main alternator and motor stators.

Excitation indicators — main alternators.

The control room also contains a direct current switchboard for distributing direct current wherever required by the main propulsion equipment. Current is received at this board from the main ship's distribution rooms.

The fireroom central control is also arranged in this room. It comprises a full set of indicating instruments, including boiler room air pressure gauges, and signalling equipment for control of fuel oil burners and fuel oil pressure together with the necessary interior communication systems.

CABLE.

All power cable used for the high voltage circuits is of the single conductor type, except that used for the motors of the main motor ventilating fans which is of the three conductor type, carrying one phase per conductor and hence is neutralized. The grouping of the single conductor cables is such as to effect as complete a neutralization of the inductive effects as possible and to equalize the load carried by the individual conductors of the same phase. The leads from alternators to control room have four conductors per phase, and those from the control room to main motors have three conductors per phase. The size of all single conductor cables is 2,500,000 C.M., and all are armored with a double wrapping of bronze tape. The armor of all cables is grounded to prevent accumulation of static, and the cables are well supported between rigidly clamped insulators of moulded insulation.

CLASS S43-1 — SHAFTING AND BEARINGS.

Details of propulsion shafting follow:

Propeller shafts — Length 41 feet 6 inches, 22½ inches O.D., 5⅞ inches I.D., O.D. at journals 25 inches.

Tube shafts — Length 46 feet 10 inches, 22½ inches O.D., 13¾ inches I.D., O.D. at journals 25 inches.

Thrust shafts — Length 30 feet 10 inches, 21 inches O.D., 13¾ inches I.D., O.D. at journals 21¼ inches.

The main thrust bearings were supplied by the Kingsbury Machine Works, of Philadelphia, Pa., and are horizontal, double split, shoe type, having six (6) ahead thrust shoes, and six (6) astern thrust shoes. Size 45 inches. Area single shoe is 169 square inches or a total thrust area of 1014 square inches each way. Forced lubrication, water cooled.

Each shaft has two steady bearings, one at each end of the thrust bearing housing, a spring bearing, a forward and an after stern tube bearing, wood lined, and a strut bearing, wood lined.

CLASS S44 — PROPELLERS.

The propellers were supplied by the Navy Yard, Philadelphia, Pa., and are of the three bladed type with dimensions as follows:

Diameter — 14 feet 10⅝ inches.

Pitch — 13 feet 3 inches.

Projected area — 109.62 square feet.

CLASS S45 — LUBRICATION.

Lubrication Systems — In general, all main alternators are supplied with an independent forced lubrication system with separate pumps, piping, control valves, oil coolers, oil purifiers, magnetic strainers, duplex mesh strainers, drain tank, emergency gravity tank, storage tank, temporary storage tank, sight glasses, thermometers, etc. The same pump that is used for the lubricating system supplies oil at a much higher pressure for the hydraulic control of the turbine, from which pressure it is reduced through a baffler type valve to a lower pressure suitable for the bearings. The gravity tank is for emergency oil supply if pump should fail, and an additional emergency feature is a cut-over valve which starts an idle pump on the line if the operating pump fails.

Each motor room is supplied with an independent forced lubrication system for the motors therein and for the thrust bearing of the corresponding shaft. The bearings of the motors have an ample oil reservoir and oil rings so that they will continue to oper-

ate satisfactorily for some time if the forced feed system fails. The forced lubrication system comprises separate pumps, piping, control valves, oil coolers, duplex strainers, oil purifier, drain tank, storage tank, sight glasses, thermometers, etc.

Each 750 Kw. ship's service generator has its own independent forced lubrication system with self-contained reservoir and geared pump.

All other rotating auxiliary steam machinery has, in general, bearing oil reservoirs and ring oilers. Rotating auxiliary electrical machinery such as ventilating blowers, etc., is supplied with ball bearings arranged for grease lubrication and fitted for use of grease guns.

A good grade of mineral oil of a viscosity of about 150 seconds Saybolt Universal, at 130 degrees F. has given excellent results on both forced lubrication and ring oiled bearings generally.

OIL COOLERS.

There are twelve (12) oil coolers installed in the machinery spaces for the lubricating oil system of the turbo-alternators, three for each system. In addition, there is one oil cooler per main motor room. All these oil coolers are of the same type as follows:

Supplied by Griscom Russel Co., of Massillon, Ohio.

Type — Navy Multi-whirl.

Capacity — 100 gallons per minute of oil having a viscosity of 500 seconds, Saybolt Universal at 100 degrees F., cooled from 140 degrees F. to 110 degrees F. when supplied with circulating water at 70 degrees F., and at a 2 to 1 ratio, that is, at a rate of 200 gallons per minute. The oil pressure drop will, under these conditions, be less than 10 pounds and the water pressure drop less than 3 pounds. Each cooler contains 300 square feet of cooling surface consisting of 336 tubes, ⅝ inch O.D., and 5 feet 8 inches long.

There is also one lubricating oil cooler for the lubricating system of each 750 Kw. ship's service generator; type, as follows:

Supplied by Andale Engineering Co., Philadelphia, Pa.

Type — Double pass marine.

Capacity — 63 gallons per minute of lubricating oil from 140 degrees F. to 115 degrees F., with cooling water at 85 degrees F., supplied in ratio of 3 to 1, that is 189 gallons per minute. Cooling

surface 109.9 square feet, 278 tubes, 5/8 inch O.D., and 2 feet 6 7/8 inches long.

OIL PURIFIERS.

Oil purifiers of the centrifugal type are installed as follows:

One for each main turbo-alternator lubricating system.

One for each main motor room.

These are all supplied by DeLaval Separator Co., New York City.

There are in addition two lubricating oil purifiers of the centrifugal type supplied by the Sharples Specialty Co., Philadelphia, Pa., for purification of airplane engine oil, located in the pump room near the storage tanks for this type of oil.

LUBRICATING OIL STORAGE.

In general, lubricating oil storage is supplied as follows:

New oil storage — 9600 gallons.

Gravity tank capacity — 2400 gallons.

Temporary (or used) oil storage — 5000 gallons.

Drain tank capacity — 9400 gallons.

CLASS S46-1 — CONDENSERS, MAIN.

There are eight main condensers installed, two for each of the main turbo-alternators, cross connected in pairs. Type and description as follows:

Supplied by Bethlehem Shipbuilding Corporation, Quincy, Mass.

" Navy" type — double pass, surface.

Cooling surface — 16,184 square feet.

Tubes — 10,693, 5/8 inch O.D., .065 inch thick, 9 feet 5 13/16 inches long.

CLASS S46-3 — CONDENSERS, DYNAMO.

There is one separate and independent condenser for each of the 750 Kw. ship's generator sets. Type and description as follows:

Supplied by Bethlehem Shipbuilding Corporation, Quincy, Mass.

" Lovekin" type — double pass, surface.

Cooling surface — 2014 square feet.

Tubes — 2204, 5/8 inch O.D., .065 inch thick, 5 feet 9 9/16 inches long.

CLASS S47 PUMPS:

There follows herewith a table showing list and description of pumps installed:

TABLE III PUMPS

Item No.: (1)	Service and no. installed: (2)	Size and type (3)	General data (4)	Location (5)	Supplied by- (6)
1	2- Bilge drain age also sani: tary system	750 g.p.m.: vertical, motor drvn, Centrifugal:	1700 r.p.m. motor, open, Comp., 230 volts: 116 amps 32 H.P.	2nd platform, Frame 43	Pump-Morris Machine Works, Baldwinville, N.Y. Motor- Gen.Elect.Co Controller - Gen.Elect.Co.
2	2- Bilge drainage	250 g.p.m.: Recipro- cating, Motor drvn: 91 ft.	Pump shaft - 83 r.p.m., Motor, Comp. open, 1000 rpm: 230 V. 30.5 Amps.8 H.P.	Hold - Frames 134 & 135	Pump- Buffalo Pump Co.,Buffalo Motor-Westing- house Co., Controller - Westinghouse Co.
3	2- Brine circulating (refrigerat- ing)	80 g.p.m. Horizontal, Motor drvn, Centrifugal: 56 ft.	1800 r.p.m. Motor, Comp. open, 230 volt: 6.25 Amps 2 HP:	For'd Re- frigerat- ing plant M.H.Deck	Pump- M. T. Davidson, New York. Motor-West.Elec. Controller - C.H. Co.
4	2- Brine circulating (refrigerat- ing)	95 g.p.m. 85 ft., horizontal, Motor drvn, Centrifugal:	1800 r.p.m., motor,Comp., open,230 V. 28.5Amps 7.5HP:	After re- frigerat- ing plant 2nd plat- form deck	Pump- M. T. Davidson. Motor- West. Elec.Co. Controller Monitor Co., Baltimore
5	2-Brine Circulating (evaporators)	200 g.p.m. per impellr: 15 ft., Hori: zontal,motor driven, cen: trifugal, 4: impellers	710 to 1150 r.p.m.,motor, comp., Wt. 230 volts, 30 amps: 5 to 6½ HP	Evap.Room hold	Pump-Bethlehem Shipbuilding Corp. Motor-Elect. Dynamic Co. Controller - C.H. Co.
6	2 Brine Discharge (Evaporators)	100 g.p.m. 72 ft. Horizontal, Motor drvn, Centrifugal:	2400 r.p.m. motor, Comp., Wt.,230 volts 23 amps., 5 HP	Evap.Room hold	Pump-Bethlehem Shipbuilding Corp. Motor-Diehl Elect.CO. Controller - C.H. Co
7	8-Circulat- ing, main con: densers	35000 g.p.m. 40 ft., Horizontal, Motor drvn, Centrifugal, three im- peller, doub: le inlet, single out- let.	1350 r.p.m. turbine,470 HP 26 in. single stage, 250 lbs steam, 25 lbs., abs. S.P., 500 superheat	One for each main condanser in machin ery spaces:	Pump -Buffalo Steam Pump Co., Buffalo, N.Y., Turbine- Terry Steam Turbine Co Hartford, Conn.

(1)	(2)	(3)	(4)	(5)	(6)
8	6 Circulating, dynamo condensers.	2700 g.p.m., 20 ft. Horiz. turbine drivn, centrifugal, single impeller.	1525 r.p.m. Turbine, 29½ HP., 18 in. single stage, 250 lbs steam, 25 lbs abs. HP, 50° superheat.	One for each dynamo condenser in machinery spaces.	Pump-Worthington Pump Co., New York, N.Y. Turbine: Terry Steam Turbine Co., Hartford, Conn.
9	2 Circulating, CO_2 condensers, (Refrigeration)	84 g.p.m., 60 ft., Horiz., motor drvn., centrifugal.	1800 r.p.m. Motor, Comp., open, 230V 19.5 amps., 5 HP	After refrig. plant, 2nd plat dk:	PUMP-N.Y. Davidson Co., Motor-Westinghouse Elect.Co. Controller-Monitor Co., Baltimore.
10	2-Circulating, distilling condensers, (evaporators)	1200 g.p.m., 40 ft. Horiz., motor drvn., centrifugal.	1450 r.p.m., motor, Comp., open 230 V., 49-94 amps., 12½-25 HP., 875-1750 g.p.m.	Evaporating plant, Hold	Pump-Bethlehem Shipbuilding Corp. Motor-Diehl Elect.Co Controller-C.H. Co.
11	4 Circulating, oil & air coolers and hydraulic vacuum pump supply	1000 g.p.m., 50 ft., on air & oil cooler circulating end. 800 g.p.m., 66 ft. on hydraulic vacuum supply end. For., turbine drive, centrifugal.	1625 g.p.m. turbine, 52 HP, 19 in. single stage, 250 lbs. steam, 25 lbs. Abs. HP, 50° superheat.	One for each oil & air coolers & hydraulic pump of turbo-alternator, Machinery spaces.	Pumps-Worthington Pump Co., Turbine: Terry Steam Turbine Co.
12	4 Circulating oil and air coolers	4500 g.p.m. 40 ft. Horiz. motor drive, centrifugal.	1700 rp.m. motor, Comp. Open, 230 V, 168-246 amps., 45-66 HP 1500-1700 r.p.m.	One in each main motor room	Pumps-Worthington Pump Co. Motors-General Elect. Co. Controllers-Gen. Elect. Co
13	8-Condensate, main condensers	1500 g.p.m., 75 ft., Horiz. turbine drivn, centrifugal.	1500 r.p.m. Turbine, 55HP 250 lbs. steam, 25 lbs Abs. HP, 50° superheat	One pair: for each pair of main condensers for each turbo-alternator	Pumps- C. H. Wheeler Co. Turbine: Terry Steam Turbine Co.
14	6 Condensate, dynamo condensers	125 g.p.m. 75 ft. Horiz. turbine drivn, centrifugal,	2500 rp.m. Turbine, 6½ HP., 16 in. single stage, 250 lbs steam, 25 lbs Abs. HP., 50° superheat.	One for each dynamo condenser	Pump- C.H. Wheeler Co. Turbine- Terry Steam Turbine Co.
15	2- Condensate, distilling condensers. (evaporators)	100 g.p.m., 55 ft. Hor., motor drive, centrifugal.	2100 r.p.m. motor, Comp., M., 230 V, 19 amps., 5 HP	Evaporating Plant, Hold	Pump- Bethlehem Shipbldg Co. Motor-Diehl Elect. Co. Controller-CH. Co.

(1)	(2)	(3)	(4)	(5)	(6)
16	8 Feed, main boiler	900 g.p.m. 900 ft. Hor. turbine drive, 3 stage centifugal	3000 r.p.m., turbine, 300 HP, 26½ in., 250 lbs steam, 25 lbs. Abs. BP, 50° superheat	FOUR IN PUMP ROOM: of each mach. Space	Pump-Buffalo Steam Pump Co. Turbine-Terry Steam Turbine Co
17	2 Feed, Aux. and make up	450 g.p.m. reciprocating, simplex, steam driven.	Size- 14 in. X 19in. X 24 in.	One in pump room: of each machinery space	Worthington Pump Co.
18	2 Feed, evaporators	200 g.p.m., 40 ft, Hor. centrifugal, motor drive.	1750 r.p.m. motor, Comp., semi-enclosed, 230 V, 12-23 amps, 3-6 HP	Evaporator room, Hold	Pump-Bethlehem Shipbldg. Corp. Motor-Diehl Elect. Co. Controller-C.H. Co.
19	4- Fire and Bilge	800 gpm reciprocating, simplex, steam	Size: 16 in. X 14 in. X 24 in.	Two in each mach: space pump room:	Worthington Pump Co.
20	2- Fire and bilge, port use.	500 g.p.m. 270 ft. Hor. motor drive, 2 stage centrifugal.	1750 r.p.m. motor, Comp., open, 230 V, 60-240 amps., 15-57½ HP	One in each Mach: space pump room:	Pump-Morris Mach. Co. Motor-Elect. Dynamic Co. Controller- Sundh Elect. Co.
21	2- Flushing (Sanitary)	1000 g.p.m., Hor. motor driven, Centrifugal.	1700 r.p.m., motor, Comp., open, 230 V. 370 amps. 100 H.P.	Hold, Frame 135:	Pump-Morris Machinery Works. Motor-G.E.Co. Controller- Gen.Elect. Co.
22	2- Fresh water distributing	200 g.p.m. Hor. motor drive, Centrifugal.	1720 -1820 rpm: motor, Comp., open, 230 V, 30.5-43 amp. 8.5- 12 HP.	Hold Frame 40	Pump-Morris Machine works Motor-Elect. Dynamic Co. Controller-CH.Co.
23	2-Freshater, distilled, evaporators	100-50 g.p.m.: 72-130 ft. head, Hor. motor drive, centrifugal.	1200-2400 rpm: motor, Comp. 230 V: 15.5-30 amp., 4-8 HP	Evaporator room, Hold	Pump-Bethlehem Shipbldg., Corp. Motor-Diehl Elect. Co. Controller-CH. Co
24	6- Fuel oil service	100 g.p.m., 700 ft. Hor., rotary: screw, turbine drive.	1200 r.p.m., turbine, 44 HP: 18 in. 250 Lbs. steam, 25 lbs. Abs. BP., 50 superheat	Three in each Mach: space pump room:	Pumps- W.E. Quimby Co., Newark, N.J. Turbine: Terry Steam Turbine Co
25	4- Fuel oil Booster	200 g.p.m. Reciprocating, simplex, steam.	Size: 8 in. x 10 in. x 12 in.	Two in each Mach pump room.	Worthington Pump Co.

(1)	(2)	(3)	(4)	(5)	(6)
26	2-Fuel oil service, port use.	5 g.p.m., 300 lbs. Hor. rotary plunger, motor driven.	450 r.p.m., motor, Comp., open, 230 V 9.4 -11.9 A. 1½-2½ HP	One in each Mach space pump room	Pump-Kinney Mfg. Co. Boston. Motor-Gen. Elec. Co Controller-Gen. Elec. Co.
27	6- Fuel oil re-circulating	400 g.p.m. Reciprocating: Steam	Size: 12 in X 10 in X 24 in	Three in each mach space pump room	Warren Steam Pump Co., Warren, Mass.
28	2- Gasolibe service	150 g.p.m. Hor., rotary plunger, motor driven	860-1150 rpm Motor, Comp., Wt. 230 V. 39.3 amp. 10HP	first platform deck	Pump-Kinney Pump Co., Boston. Motor-Gen. Elect. Co Controller: GE. Co
29	2- Gasoline system, salt water exchange	250 g.p.m. Hor. Motor driven, centrifugal.	1700-1870 r.p.m Motor, Comp., Wt: 230 V. 38.5 A.: 10 HP	2nd platform deck	Pump-Morris Machine Works. Motor-Gen. Elec. Co. Controller-GE. Co.
30	8-Lubricating oil, main turbo-alternators	325 g.p.m. 230 ft. Hor., rotary screw, turbine driven	950 rpm. Turbine 60 HP, 24 in, 250 lbs. steam. 25 lbs. Abs. HP. 50° superheat.	Two for each main turbo-alternator	Pump-W. E. Quimby Co. Turbine-Terry Steam Turbine Co.
31	8-Lubricating oil, main motors.	100 g.p.m. 50 ft. Hor. rotary screw, motor driven.	1200 rpm motor, shunt, open, 230 V. 48 A. 13 HP	Two for each main motor room	Pump-W. E. Quimby Co Motor-Elect. Dynami: Co. Controller-GE-Co.
32	2 Lubricating oil, airplane engine service	45 gpm Hor. rotary plunger, motor driven.	400-1200 rpm motor, Comp. open, 230 V. 6.5-14 A. 1-3 H.P.	Hold	Pump-Kinney Mfg. Co. Motor-Gen. Elect. Co. Controller-GE. Co.
33	8-Vacuum, hydraulic, air cooler systems of main alternators	20 cu. ft. for free air per min. at 80 F. and 13 ft. Abs. pressure	---	Two for each main alternator cooling system	Worthing Pump and Machinery Corp. Harrison, N.J.
34	2-Airplane elevator service.	Reciprocating, motor driven.	Starts at 1050 lbs. Stops at 900 lbs.	Third deck	Worthington Pump Co.
35	10 Submersible portable	180 g.p.m. 50 ft. motor drive, centrifugal.	2250 rpm. motor Comp. special, 230 V. 8 a. 2 HP	Portable	Pump-Baldwin and O'Laughlin, New York. Motor-Star Elect. Co., Newark, N.J.

CLASS S46-4 — AIR EJECTORS.

There are eight main air ejectors, two to each pair of condensers installed for each of the turbo-alternators.

Type and description as follows:

Supplied by C. H. Wheeler Co., Philadelphia, Pa.

Type — Twin, two stage radojets with intercondenser.

Working pressure steam — 125 pounds per square inch.

Intercondenser tubes — 292, 5.8 inches O.D., .065 inch thick, 18 inches long.

In addition there are six air ejectors, one for each of the condensers installed for the 750 Kw. ship's service generators, type and description as follows:

Supplied by C. H. Wheeler Co., of Philadelphia, Pa.

Type — Single, two stage radojets with intercondenser.

Intercondenser tubes — 64, ⅝ inch O.D., .065 inch thick, 17½ inches long.

CLASS S48 — DRAINAGE SYSTEM — ENGINEER DEPARTMENT.

The high pressure steam drain system is interesting in that practically all individual traps have been eliminated and the drains are all connected to a high pressure drain loop, one in each machinery space. Each loop in turn connects to a high pressure drain tank, the discharge of which is controlled by an automatic float equipment.

The low pressure steam drain system utilizes thermostatic valve traps of the Sarco or Hoffman return line valve type on the individual heater or point to be drained. The thermostatic valve discharges pass via check valves to a common return.

The fuel oil service tank heating coils, whistle and siren, and steam line ahead of each main throttle use bucket traps. The traps for the former discharge to a common line connecting to the fuel oil heater drain inspection tanks of which there are two, one in fireroom 5 and one in fireroom 13. The drains from the fuel oil service and recirculating heaters are also led via water seals to the inspection tanks. Each inspection tank has a condenser included in the design to cool any vapor which may flash from the drains.

There is also a fresh water collecting system in each machinery space which collects the fresh water from atmospheric sight flows, etc.

In addition salt water and other leakage from pump glands, etc., is collected and returned to a bilge sump tank in an effort to keep the bilges as dry as possible.

CLASS S49 — COMPRESSED AIR SYSTEM.

Air compressors are installed as follows:

(*a*) 3 — Torpedo Air Compressors: Supplied by Platt Iron Works, Dayton, Ohio. Four stage, 50 cubic feet per hour at 3000

pounds per square inch gauge, motor driven, 500 R.P.M. Motor, shunt wound, open, 230 volts, 340 ampères, 85 H.P. Motor and controller supplied by General Electric Co.

(*b*) 2 — Engineering Air Compressors: Supplied by Ingersoll Rand Co., New York. Two stage, 175 cubic feet of free air per minute at 200 pounds per square inch gauge, motor driven, 400 R.P.M. Motor, compound wound, open, 230 volts, 206 ampères, 56 H.P. Motor and controller supplied by General Electric Co.

(*c*) 2 — Engineering Air Compressors: Locomotive type, supplied by Westinghouse Air Brake Co. Vertical, steam driven, 11 inches by 11 inches, by 12 inches, 35 cubic feet free air per minute at 150 pounds per square inch gauge.

(*d*) 2 — Gas Ejector (and Catapult) Compressors: Supplied by Ingersoll Rand Co., New York. Two stage, 350 cubic feet of free air per minute at 450 pounds per square inch, motor driven, 375 R.P.M. Motor, compound, open, 230 volts, 529 ampères, 150 H.P. Motors and controllers by General Electric Co.

(*e*) 2 — Control Room Compressors: Supplied by General Electric Co., for pneumatic system of the main propulsion control. Twin cylinder, single stage, motor driven, 190 R.P.M. Capacity, 23.5 cubic feet of free air per minute at 90 pounds gauge.

(*f*) 1 — Incinerator Compressor: Supplied by Chicago Pneumatic Tool Co. Single stage, twin cylinder, motor driven, 800 R.P.M. Capacity, 100 cubic feet free air per minute at 40 pounds gauge. Motor, 230 volts, 75 ampères, 20 H.P.

The air systems distribute air for the following services and at the approximate pressures shown:

Torpedo Charging — 3000 pounds.
Elevator Air Banks — 1200 and 800 pounds.
Fire Extinguishers — 800 and 75 pounds.
Recuperator Cylinders — 2000 pounds.
Loading Rammers — 500 and 125 pounds.
Arresting Gear — 150 pounds.
Tail Rope Tension Cylinders — 450 and 90 pounds.
Gas Ejectors — 200 and 175 pounds.
Conning Tower Gas Ring — 175 pounds.
Ship's Service Air Bank — 200 and 100 pounds.

Cleaning Electrical Machinery — 100 and 30 pounds.
Main Propulsion — 100 pounds.
Incinerator Service — 40 pounds.
Shop Service — 100 pounds.
Fuel Oil Blow Service — 100 and 18 pounds.
Pneumercator Supply Service — 100 and 43 pounds.
Pneumatic Tube Service — 40 and 5 pounds.
Humidifier Supply Service — 40 and 15 pounds.

CLASS S51 — BOILERS.

Sixteen boilers are installed in an equal number of firerooms disposed outboard of the machinery spaces on both sides. All starboard boilers are directly connected to the smoke pipes on the starboard side; four smoke pipes incased, two starboard boilers and two port boilers per smoke pipe. The port boilers are connected to the same smoke pipes on the starboard side by eight cross-overs passing just above the third deck, one boiler per cross-over.

A description of the boilers is as follows: Supplied by Bethlehem Shipbuilding Corporation, Quincy, Mass.; superheaters by the Babcock and Wilcox Company, of New York. Oil burning, Yarrow Type, heating surface 11,250 square feet, superheating surface 797 square feet. Tubes: 3398 tubes 1¼ inches O.D., .109 inch thick, and 266 tubes 1½ inches O.D., .120 inch thick. Safety valve setting 295 pounds gauge. Water per boiler at steaming level 4050 gallons, full 5343 gallons. Each boiler equipped with 8 Lodi Type fuel oil burners and air registers, one Astor-Anthony Feed Water Regulator, 2 (valve in head) Diamond Soot Blowers, and 2 smoke periscopes, one in each pass. Water gauge glasses are two in number, one of the reflex, and one of the plain flat glass type. Both molded fire brick and plastic fire brick are used for lining furnaces, placed inside of molded diatomaceous earth insulating brick on back and side walls, with split fire brick over granular calcined diatomaceous earth on floors. Plastic and brick are secured with manganese nickel bolts.

CLASS S53 — BLOWERS, FORCED DRAFT.

Air for the starboard forced draft blowers is usually taken by vertical doors in the vessel's side. These doors are protected by a spray shield, and open outboard about on the level of the upper

half deck. They may be closed from the inside of the ducts leading to the forced draft blowers located on the third deck. Air for the port forced draft blowers is usually taken via horizontal doors opening into boat pockets and open passage ways on the port side about the level of the main deck. In both cases, however, all these doors may be closed and air for the forced draft blowers admitted via both horizontal and vertical doors leading from the hangar deck spaces. Air for ventilation of the main machinery spaces is taken from the same ducts which supply the forced draft blowers.

There are thirty-two forced draft blowers, two per blower room serving each of the sixteen firerooms. A description of the forced draft blowers is as follows: Supplied by the Sturtevant Company, of Hyde Park, Mass. Horizontal, double ended (two fans per turbine, overhung) multi-vane type, turbine driven, capacity 35,000 cubic feet per minute at a normal static head of 8 inches of water. Turbine: 90 H.P., 1650 R.P.M., 250 pounds gauge, 10 pounds gauge back pressure, 24-inch wheel.

CLASS S55 — FUEL OIL EQUIPMENT.

Fuel oil is distributed via four relay tanks, two on each side, to nine fuel oil service bottoms, eighty-nine fuel oil storage tanks, and twenty-four emergency fuel oil storage tanks; the storage tanks are outboard of the machinery spaces on both sides and in the double bottom compartments. A considerable weight of fuel oil (or water) must be used at all times to compensate for the extra weight on the starboard side of the vessel consisting of the turrets, bridge structure, and smoke pipes and casing. Total usable fuel oil is about 5400 tons.

The various items comprising the fuel oil equipment are described as follows, (for fuel oil pumps see Class S47):

TANK GAUGES.

Tank gauges are of the Pneumercator Type, supplied by the Pneumercator Tank Gauge Co., New York.

FUEL OIL PURIFIERS.

There are two fuel oil purifiers located one in a starboard, one in a port side relay tank room. They are of the centrifugal type

furnished by the DeLaval Separator Co., of New York. Motor driven at 1750 R.P.M. by a shunt wound, 2 H.P., D. C. motor.

FUEL OIL SERVICE HEATERS.

There are sixteen fuel oil service heaters located one per fireroom, supplied by Schutte & Koerting Co., Philadelphia. Capacity 12,500 pounds per hour of fuel oil with viscosity of 700 seconds Saybolt Furol at 70 degrees F., imparting a temperature rise of 200 degrees F. maximum. Heating surface 173.6 square feet with 212 tubes ⅝ inch O.D., 16 B.W.G., 5 feet 2¾ inches long. Steam at full boiler pressure is used and drained through water seal to inspection tank. Each heater is controlled by a temperature regulator of the thermostatic syphon type. Full boiler steam pressure is used.

FUEL OIL RECIRCULATING HEATERS.

There are six fuel oil recirculating heaters located three per pump room of each machinery space. Supplied by Griscom-Russell Co. of Massillon, Ohio. Three pass type with capacity of 160,000 pounds per hour of fuel oil with a viscosity of 700 seconds Saybolt Furol at 70 degrees F. imparting a temperature rise of 100 degrees F. maximum, using steam at boiler pressure. Heating surface 412 square feet, with 540 tubes, ⅝ inch O.D., 18 B.W.G., 4 feet 11½ inches long.

FUEL OIL METERS.

Two service fuel oil meters are installed, supplied by National Meter Co., New York. Capacity, 100,000 pounds per hour.

Two smaller meters are used in the recirculating system for hot clearing oil.

FUEL OIL ATOMIZERS.

Eight fuel oil atomizers of the "Lodi" type are installed per boiler. Supplied by the Babcock and Wilcox Co., New York. Maximum designed capacity 1500 pounds fuel oil per hour each at 300 pounds pressure.

CLASS S56 — FEED WATER EQUIPMENT.

There are four main feed tanks, two per machinery space, all cross connected. Total capacity of each is 9910 gallons. Each tank contains a filter chamber, and an after condenser for radojet discharges is located in each. The latter contains 333 tubes, 1 inch O.D., 2 feet 7¼ inches long. The feed pumps are covered under Class S47.

The feed system, in general, consists of four groups of two pumps each, supplying two independent feed lines feeding separate and independent feed stop and check valves on each boiler. The two forward groups of pumps supply one feed system, and the two after groups of pumps supply the other. The boilers may be fed by hand or by the Astor-Anthony Feed Regulators installed one per boiler. The feed pumps, in addition to the usual turbine governors, are regulated by S-C type differential pressure governors maintaining a fixed differential in the feed pump discharge pressure over that of the boiler steam.

FEED WATER HEATERS.

There are four feed water heaters, one for each feed pump group. These are of the straight tube type with a capacity of 587,000 pounds of feed water per hour each, raised from 90 degrees to 225 degrees F., when supplied with exhaust steam at 240 degrees F. They were supplied by Griscom-Russel Co., and each has 1170 square feet of heating surface, with 828 tubes ⅝ inch O.D., 18 B.W.G., 9 feet 1 inch long.

SALINITY INDICATORS.

Electric salinity indicators are installed for feed tanks and condensate pump discharges. Similar salinity indicators are installed for use with the distilling plant.

FEED WATER SUPPLY.

The feed water supply is distributed in eighteen reserve feed bottoms, total capacity 195,585 gallons.

In addition, there is an emergency feed water capacity, available in eighteen emergency reserve feed bottoms, of 336,875 gallons.

CLASS S58 — DISTILLING PLANT.

The distilling plant consists of two main evaporating units, with two distilling condensers, and the necessary auxiliary machinery. The plant was supplied by the Bethlehem Shipbuilding Corporation, of Quincy, Mass., and may be described as follows:

EVAPORATING UNIT.

Low pressure type, quadruple effect. Each effect contains a nest of 193 copper tubes 1½ inches O.D., 5 feet 8 inches long, .072 inch thick expanded at both ends into tube sheets and the whole contained in a suitable steel shell.

Heating surface of each effect is 4010 square feet, and each effect is fitted with automatic feed regulator, internal coil drain regulator, etc.

Capacity each unit is 33,000 gallons per twenty-four hours with first effect steam at 10 pounds gauge, and fourth effect vacuum at 27 inches Hg. Overload capacity (clean tubes), 43,000 gallons per twenty-four hours.

DISTILLING CONDENSER.

Curved tube type expanded into tube sheets at both ends; 757 tubes in two passes; total cooling surface 663 square feet. There are two additional passes from which evaporator feed is taken.

EQUIPMENT.

Equipment in general, includes air ejectors (radojet type), tube nest drain regulators, tube nest drain feed heaters, vapor feed heaters, fresh water meters, venturi meters, and all the necessary pumps, see Class S47.

CLASS S59 — REFRIGERATING PLANT.

There are two refrigerating plants installed, one on middle half deck, port, frame 69, and the other on 2nd platform deck, frames 134-136. The forward plant supplies cooling brine for scuttle butts, photographic laboratory, and central station cooling. The after plant supplies refrigerating brine to the cold storage compartments, scuttle butts, and for ice making.

FORWARD REFRIGERATING PLANT.

This plant consists essentially of two motor driven CO_2 compressors supplied by the Brunswick Kroeschell Co. Each compressor is rated at 6 tons capacity. The motors are supplied by Westinghouse and are shunt wound, 230 volts, 20 H.P., 150 to 225 R.P.M., with controller by Cutler-Hammer Co.

The CO_2 condenser is of the double tube type in two sections.

The brine cooler is of the shell and coil type in two sections.

The pumps are as per Class S47.

AFTER REFRIGERATING PLANT.

This plant consists essentially of three motor driven CO_2 compressors supplied by the York Manufacturing Co. Each compressor is rated at 6-ton capacity, and is of the double cylinder, single acting, vertical type. The motors are supplied by Westinghouse and are compound wound, 230 volts, 14.5 to 22.5 H.P., 160 to 250 R.P.M., with controllers by Monitor Controller Co., of Baltimore.

The CO_2 condenser is of the shell and coil type in three sections.

The brine cooler is also of the shell and coil type in three sections.

The pumps are as per Class S47.

ICE MAKING BOX.

An ice making box, supplied by York Manufacturing Co., is installed in after refrigerating plant space with capacity of 1800 pounds ice per twenty-four hours.

CLASS S61 — SHIP'S SERVICE GENERATORS.

The ship's service direct current turbo-generators, also used as exciters for the main turbo-alternator, are six in number and located three per machinery space on an upper platform over each pump room. Each set has its own condenser and necessary auxiliaries located in pump room below. A direct current switchboard is located on the same level alongside of each set of three generators and from this board power is sent to the two distribution room switchboards and to the direct current board in the control room.

These direct current generating sets were supplied by the General Electric Company and have characteristics as follows:

TURBINES.

Horizontal, four stage, Curtis (impulse) condensing type, 5000 R.P.M. Designed for steam pressure at 250 pounds gauge, 50 degrees F. superheat, and back pressure of 1½ inches Hg., absolute. Under designed conditions the unit is capable of carrying 938 Kw. output for two hours. Rated full load of 750 Kw. can be carried continuously with steam at 200 pounds gauge, and back pressure as above. A cross section of turbine is shown by Figure 8. Labyrinth steam sealed packing is used in glands.

REDUCTION GEARS.

The reduction gear is of the single reduction forced lubrication type, see Figure 9. The reduction ratio is 5000 to 800 R.P.M.

DIRECT CURRENT GENERATORS.

The generator is shunt wound, 8-pole, 240-volt, 3125 amperes, 750 Kw., 800 R.P.M. The design includes commutating poles, compensating windings in the pole faces, and multiple drum armature windings. Cross section of generator is shown by Figure 10.

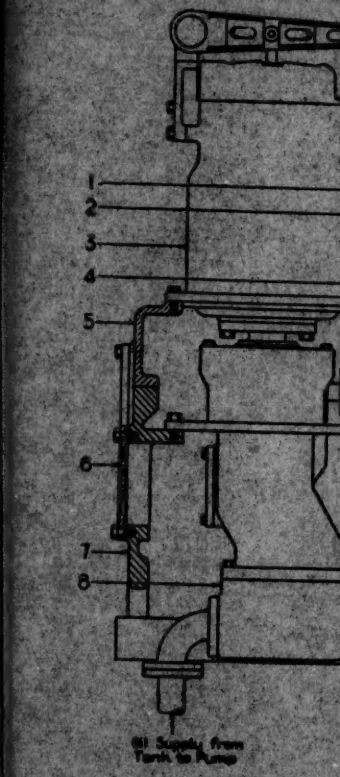
The features of these generators distinguishing them from generators usually encountered in the Naval Service are the fact that they are 2-wire shunt wound, thus eliminating the need for equalizers in parallel operation, and the compensating pole face windings. The voltage necessary for ship's lighting service is obtained from lighting motor generators located in the distribution rooms, refer to Class S63.

CLASS S62-1 — SWITCHBOARDS.

There are four main direct current switchboards and numerous smaller switchboards located throughout the vessel. The four main switchboards are described briefly as follows:

(*a*) D. C. switchboard, forward machinery space, consists essentially of five panels, viz: (1) No. 1 750 Kw. set, (2) No. 2 750 Kw. set, (3) No. 3 750 Kw. set, (4) No. 1(A) booster set, and (5) No. 2(B) booster set.

(*b*) D. C. switchboard, after machinery space, is same as item (a) for Nos. 4, 5, and 6 750 Kw. sets, and Nos. 3(C) and 4(D) boosters.



1. Hydraulic Valve Gear (
Figs. 4 and 9).
2. Emergency Trip (See Fig
and 9).
3. Main Governor (See Figs. 4
5).
4. Bearing Cap
5. Cap for Bearing Standard
6. Cover
7. Bearing Standard
8. Oil Pump (See Fig. 11)
9. Control Valves (See Figs. 4
6)
10. High-pressure Head and S
(Upper Half)

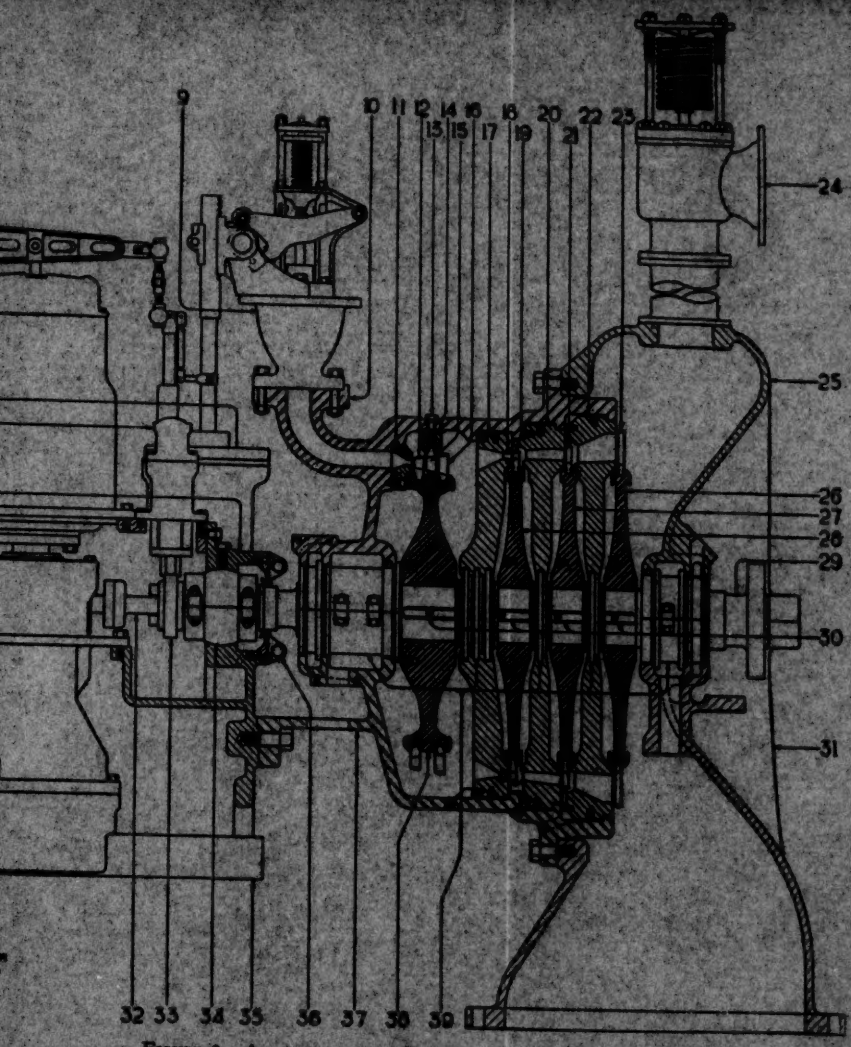
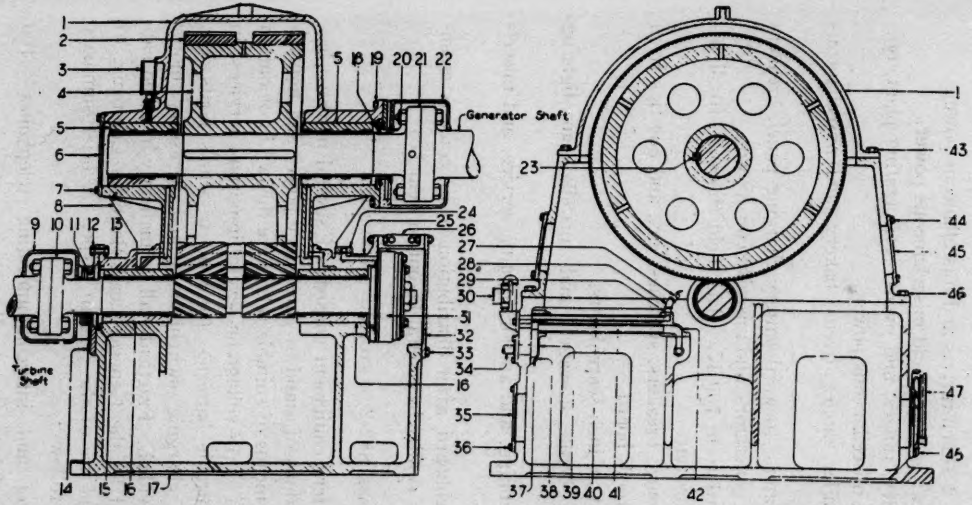


FIGURE 8.—ASSEMBLY OF 750-KW. TURBINE.

ve Gear (See
).
(See Figs. 4
(See Figs. 4 and
Standard
d
Fig. 11)
(See Figs. 4 and
Head and Shell

11. First-stage Nozzle Plate
12. First-stage Buckets, First Row
13. Holding Screws for Part 14
14. Intermediate Bucket Segment
15. Intermediate Buckets
16. First-stage Buckets, Second Row
17. Nozzle Diaphragm, Second Stage
18. Nozzle Ring, Second Stage
19. Second-stage Buckets
20. Nozzle Diaphragm, Third Stage
21. Third-stage Buckets
22. Nozzle Diaphragm, Fourth Stage
23. Fourth-stage Buckets
24. Atmospheric-relief Valve
25. Exhaust Casing (Upper Half)
26. Bucket Wheel, Fourth Stage
27. Bucket Wheel, Third Stage
28. Bucket Wheel, Second Stage
29. Turbine Main Shaft
30. Keys (See Fig. 7)
31. Exhaust Casing (Lower Half)
32. Coupling
33. Emergency Governor
34. Turbine End Bearing (See Fig. 7)
35. Support for Bearing Standard
36. Oil Deflector (See Fig. 7)
37. High-Pressure Head and Shell (Lower Half)
38. Bucket Wheel, First Stage
39. Shaft Packings—High Pressure, Interstage and Low Pressure



1 Gear Casing (Upper)
2 Gear Tire
3 Oil-pressure Gauge
4 Gear Hub
5 Bearing
6 Cover
7 Tap Bolt
8 Gear Casing (Middle)
9 Coupling Guard
10 Shaft and Pinion
11 Oil Deflector
12 Bolt and Nut
13 Bearing Cap
14 Tap Bolt
15 Oil Guard
16 Bearing
17 Gear Casing (Lower)
18 Oil Guard
19 Tap Bolt
20 Oil Deflector
21 Gear Shaft
22 Coupling Guard
23 Key
24 Sight-flow Indicator
25 Bearing Cap
26 Cover
27 Oil Nozzle
28 Elbow
29 Nipple
30 Sight-flow Indicator
31 Thrust Bearing (See Fig. 10)
32 Cover
33 Tap Bolt
34 Feed Pipe
35 Cover
36 Tap Bolt
37 Lock Washer
38 Bolt
39 Oil Manifold
40 Pipe
41 Pipe
42 Oil-nozzle Support
43 Tap Bolt
44 Tap Bolt
45 Cover
46 Tap Bolt
47 Thermometer
48 Oil Gauge

FIGURE 9.—REDUCTION GEAR ASSEMBLY.

(*c*) D. C. switchboard, forward distribution room, consists essentially of ten panels, viz:

(1) Nos. 1 and 2 8-inch turrets and miscellaneous power.

(2) Steering gear, elevators and miscellaneous power.

(3) Crews' galley, ranges, and ovens, refrigerating plant, officers' quarters, and miscellaneous power.

(4) Officers' galley ranges, ovens, bakery, and miscellaneous power.

(5) Radiant heaters, forward battery charging panel, breakers for lighting motor generators, and miscellaneous power.

(6) Power board from 750 Kw. flats, field rheostats for lighting motor generators, etc.

(7) Lighting board, breakers, switches, etc., and bus ties from after distribution room board.

(8) 24-inch and 36-inch searchlights.

(9) Magazines, bomb stowages, and miscellaneous lighting service.

(10) Signal, running, and anchor lighting service, and miscellaneous lighting.

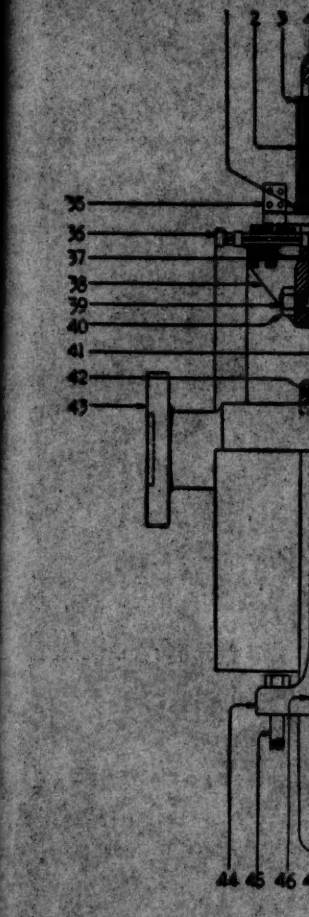
(*d*) D. C. switchboard, after distribution room, consists essentially of ten panels similar in general layout to item (*c*).

CLASS S62-2 — STORAGE BATTERIES.

The storage battery equipment consists of several more or less permanent installations of stand-by emergency power and lighting batteries which by means of suitable relays are thrown in or out on failure or return of ship's voltage on several important services; in addition, small portable batteries are used in ship's boats, etc. Complete battery charging switchboards and necessary motor generators are provided. Practically all permanently installed batteries are supplied by the General Lead Batteries Company, of Newark, N. J., and are of the "Titan" type. A brief summary of these batteries follows:

(*a*) Fire control and intercommunicating telephones — 100 ampère hour "Titan" battery, 4 3-cell trays.

(*b*) Ship's service and general announcing telephones — 100 ampère hour "Titan" battery, 4 3-cell trays.



1. Collar
2. Field coil
3. Collar
4. Spool body
5. Assembly of pole piece pu
6. Bolt hex. head
7. Magnet Frame (upper ha
8. Conductor (pole face wi
9. Tube
10. Equaliser bar
11. Commutator lead
12. Commutator lead (equali
13. Armature flange (comm
end)
14. Bolt hex. head
15. Bus ring cir
16. Bus ring
17. Contact plate
18. Equaliser bar
19. Brush-holder yoke
20. Assembly of brush

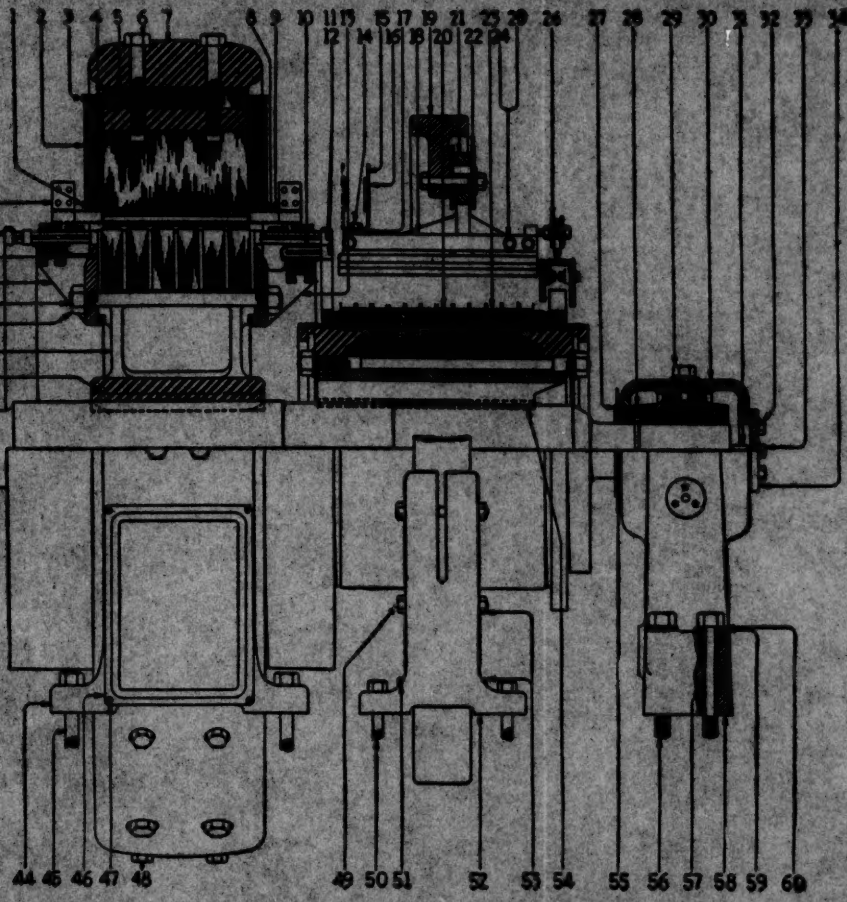


FIGURE 10.—750-KW. SHUNT-WOUND GENERATOR.

pole piece punchings
d
e (upper half)
ole face winding)
r
lead
lead (equalizer)
ange (commutator
d
yoke
brush

31. Brush-holder bracket
32. Assembly of insulation for brush-holder bracket
33. Assembly of commutator
34. Bolt hex. head
35. Washer
36. Assembly of guard rings
37. Oil deflector
38. Bearing
39. Set screw
40. Cap
41. Tachometer plug
42. Tap bolt, hex. head
43. Pipe plug
44. Cover
45. Clip
46. Assembly of armature winding
47. Assembly of armature punchings
48. Armature flange (back end)
49. Stud
50. Nut, hex.
41. Armature spider
42. Key
43. Shaft
44. Magnet frame (lower half)
45. Tap bolt, hex. head
46. Cover
47. Mach. screw, round head
48. Bolt, hex. head
49. Bolt, hex. head
50. Bolt, hex. head
51. Bolt, hex. head (semi-finish)
52. Brush-holder yoke support
53. Nut, hex.
54. Key
55. Air shield
56. Bolt, hex. head
57. Insulation bushing
58. Standard
59. Insulation washer
60. Washer

(*c*) Electric log — 100 ampère hour "Exide" battery, 4 3-cell trays.

(*d*) Auxiliary power, I.C. and F.C. motor generators — 300 ampère hour "Titan" battery, 84 3-cell trays.

(*e*) Auxiliary lighting forward — 200 ampère hour "Titan" battery, 42 3-cell trays.

(*f*) Inter communication systems — 300 ampère hour "Titan" battery, 4 3-cell trays.

(*g*) Portable batteries, motor boats — 100 ampère hour "Exide" batteries, 24 3-cell trays.

(*h*) Auxiliary lighting, aft — 200 ampère hour "Titan" battery, 21 3-cell trays.

(*i*) Auxiliary power, steering gear — 300 ampère hour "Titan" battery, 126 3-cell trays.

(*j*) Auxiliary lighting, steering gear — 50 ampère hour "Titan" battery, 60 3-cell trays.

CLASS S63 — LIGHTING MOTOR GENERATORS.

Two lighting motor generators are installed in each distribution room. The motor generators transform the 240 direct current voltage of the ship's turbo-generators to 120 volt direct current for use on lighting systems. The lighting voltage is adjusted to an operating standard of 115 volts and there are two voltage regulators per distribution room which automatically hold the delivered voltage of the lighting motor generators within close limits.

The lighting motor generators are supplied by the General Electric Company and each consists of a 190 H.P. direct current motor driving a shunt wound generator rated at 125 volts, 1000 ampères, 125 Kw., at 1200 R.P.M.

The voltage regulators are supplied by the General Electric Co., and each is driven by a 145-volt, 18-ampère, 2.8 H.P., 1700 R.P.M. shunt wound motor.

CLASS S65 — INTERIOR COMMUNICATION SYSTEMS.

The interior communicating systems are very complete and diversified. The main equipment consists of voice tubes, intercommunicating anti-noise telephone systems, ship's service telephones and switchboard, call bells, and annunciators, general an-

nouncing telephone system, electrical and mechanical telegraph and indicator systems, fire alarm and general alarm bells, and various bell and light alarm systems.

CLASS S66 — SEARCHLIGHTS.

High intensity 36-inch searchlights, 24-inch high intensity, and 12-inch signal searchlights are installed on bridge structure and smoke pipe casing.

CLASS S67 — RADIO EQUIPMENT.

In general the radio equipment includes sending and receiving equipment radio compasses, underwater sound outfit, and "fathometer" or depth indicating outfit. The entire equipment is the most complete and diversified to be found on any vessel at the present time. Briefly, the outfit is outlined as follows:

1 — Main transmitter, Type I, 10 Kw. (40 Kw.), about four times as large as any used on shipboard at present.

1 — Model "TP" transmitter, same as used on capital ships of the Navy.

2 — Model "TW" transmitters, same as used on destroyers, etc., of the Navy.

1 — Model "TO" transmitter, same as used on large auxiliary vessels of the Navy.

1 — Model "TU-3" transmitter, same as used on cruisers of the Navy.

13 — Receivers (Models "RE," "RF," and "RG") similar to those in use throughout the Navy.

4 — Radio compasses of an experimental type.

The underwater sound outfit consists of one "MV" compensator, Bureau type blisters and microphones, and Submarine Signal Co. oscillators.

In general, the aircraft radio equipment will consists of three types of transmitters and two types of receivers.

CLASS S72 — 8-INCH TWIN MOUNT AND AMMUNITION EQUIPMENT.

Each of the four 8-inch twin mounts are served by a 15 H.P. training motor driving a hydraulic variable speed gear of the

Waterbury type, and a 10 H.P. elevating motor driving a similar speed gear. Shells and powder are furnished to the twin mounts by several motor driven hoists of the "dredger" type. A motor driven rammer is provided for each gun.

CLASS S75 — BOMB AND TORPEDO ELEVATORS.

There are two motor driven bomb elevators and one torpedo elevator installed for service of the airplanes on hangar deck.

CLASS S78 — ANTI-AIRCRAFT AMMUNITION EQUIPMENT.

Ammunition is supplied to the four groups of anti-aircraft guns by means of both "pusher" and "dredger" type motor driven hoists; the former type using a hydraulic variable speed gear. There are also two motor driven ammunition conveyors on the main half deck aft.

CLASS S82 — SMALL BOATS.

The allowance of ship's boats for a vessel of this size is decidedly limited. The boats carried, except for motor life boats, are all equipped with Navy V-Type engines, and are as follows:

1 — 50-foot motor launch.
1 — 50-foot motor launch — "Crash Boat," fitted with about 18 tons of emergency equipment.
1 — 40-foot motor boat (barge)
2 — 40-foot motor boats.
1 — 40-foot motor launch.
1 — 36-foot motor launch.
1 — 30-foot motor launch.
2 — 26-foot motor life boats.
1 — Racing cutter.

The stowage of a considerable percentage of the boats in boat pockets necessitates rather an elaborated hoisting and stowage equipment. In general, the electrical equipment for handling boats consists of the following:

2 — Compound, geared, reversible winches, 43.75 H.P. each.
11 — Reversible boat davit motors, 5 H.P. each.
1 — Hydraulic winch, 40 H.P.
2 — Reversible winches, 9 H.P. each.

One of the 43.75 H.P. winches is located in the winch house on the flight deck at frame 90, and hoists all boats above the flight deck on the starboard side of the ship. The other winch of this size is located on the port side of upper half deck at frame 100 and hoists the boats in the two forward boat pockets.

One 5 H.P. motor is installed in each of the five boat pockets for training the davits in each recess. One 5 H.P. motor is used to rig in and out each davit at the boat stowage on the flight deck starboard; both motors which operate a pair of davits are controlled by same push button and stopped by limit switches at end of davit travel.

The 40 H.P. hydraulic winch is installed amidships at frame 149 and supplies hydraulic power for hoisting the two 50-foot motor launches into boat pockets, one on either side of ship.

The two 9 H.P. winches are connected to winding drums in the boat pocket for the 30-foot motor launch port side to hoist and stow this boat.

CLASS S83 — AIRPLANE HANDLING EQUIPMENT.

The elevators used for bringing airplanes from the hangar deck to the flight deck are covered under Class S16.

AIRPLANE CRANE.

There is one airplane crane supplied by the Bethlehem Shipbuilding Corporation, installed on the starboard side of flight deck forward. This crane is designed for a working load of 12,000 pounds at 80 feet per minute or 20,000 pounds at 40 feet per minute; the former at 30 feet from vessel's side and the latter just clear of ship's side. The crane will handle the working loads with vessel heeled up to 10 degrees. Further the working load can be rotated 35 degrees to either side of the fore and aft center line.

AIRPLANE CAPSTANS.

There are thirteen motor driven airplane capstans mounted at various locations on the main, second, and hangar decks. These are supplied by the Bay City Foundry and Machine Co., Bay City,

Mich., and each has a capacity of 1500 pounds at 37 R.P.M. Each is driven by a compound wound 9 H.P. motor.

AIRPLANE WINCHES.

There are three motor driven airplane winches mounted on the main deck. These are supplied by the same company as the capstans and are driven by a compound wound 20 H.P. motor.

In addition to the foregoing a launching catapult and an extensive arresting gear equipment are provided for airplane handling.

CLASS S85 — PHOTOGRAPHY.

A complete equipment for photography, both motion and still, is provided and fully equipped for printing and developing.

CLASS S91 — WORKSHOPS.

Fully equipped shops for airplane repair and overhaul are provided as well as a general workshop and an electrical repair shop for ship's use. A woodworking shop, a blacksmith shop, a coppersmith shop, a foundry, a sheet metal shop, and an optical repair shop are also provided.

A brief summary of the more important repair equipment follows:

PORTABLE.

Pipe threading and cutting machine, motor driven.
Gas welding outfit.
Twin pole electric arc welding outfit.

RADIO REPAIR SHOP.

Electric drill.
Grinder, motor driven.
Electric oven.
Rivet precision lathe.

OPTICAL REPAIR SHOP.

Grinder, electric driven.
Bench drill, electric driven.
Universal milling machine.
Precision lathe.

SAWMILL.

Surfacer, motor driven.
Variety saw, motor driven.

WOODWORKING SHOP.

2 Grinders, motor driven.
Sensitive drill, motor driven.
Band saw, motor driven.
Lathe, motor driven.
Jointer, motor driven.

WING COVERING SHOP.

2 Sewing machines, motor driven.

ELECTRIC WORKSHOP.

Sensitive drill, motor driven.
Armature coil spreader.
Armature coil winder, motor driven.
Grinder, motor driven.
Coil winding machine.

FOUNDRY.

Ferrous and non-ferrous electrical arc furnace; single phase, 60 Kva, 60-cycle, 90-volt, supplied with transformer 220 to 90 volts, and rocking motor.

GENERAL WORKSHOP.

Hack saw, motor driven.
Drill grinder, motor driven.
Arbor press.
Grinder, motor driven.
Universal milling machine, motor driven.
Planer, open side, motor driven.
Radial drill, motor driven.
Sensitive drill, motor driven.
Extension gap lathe, motor driven.
3 Tool room lathes, motor driven.

THE FOLLOWING UNOFFICIAL DATA INDICATES THE RESULTS
OBTAINED ON CERTAIN PRELIMINARY ACCEPTANCE TRIALS AT REDUCED POWERS.

	4 Hrs. at 140000 SHP	4 Hrs. at 226 RPM	4 Hours at 148 RPM		4 Hrs. at 144 RPM		4 Hrs. at 4500 SHP.	
			2 Hr. water rate	2 Hr. fuel Cons.	2 Hr. Water Rate	2 Hr. Fuel Cons.	2 Hr. Water Rate	2 Hr. Fuel Cons.
Average Speed in Knots	32.31	25.93	18.58	18.59	16.58	16.6	10.50	10.76
Trim - by the stern	2'8"	2'11"	3'2"		2'4"		2'6½"	
Average S.H.P. - calculated from motor input multiplied by motor efficiency	136206	67942	25198	25104	17230	17304	4266	4667
* Total Oil, gals. per hour at 60 degrees F.	23272	11371	4143	3952	2923	2807	1416	1257
* Total Oil, lbs. per hour.	186000	90650	33030	31570	23370	22420	11300	10020
* Oil per s.h.p., pounds per hour	1.365	1.333	1.311	1.257	1.355	1.295	2.643	2.143
Oil per square foot heating surface, pounds per hour.	1.033	.672	.587	.561	.519	.498	.335	.297
* Oil per knot, pounds.	5760	3499	1778	1698	1409	1351	1076	952
* Water consumption of "D" main turbine based on shp generated by D turbine, pounds per shp per hour, live steam only.	14.52	15.05	13.78	- -	13.42	- -	1663	--
Steam at boilers, gauge.	277	278	272	272	270	270	267	269
Steam at turbines, gauge.	239	237	253	255	263	263	265	266
Steam at turbine "D" - temperature Degrees F.	457	441	450	448	431	431	421	424
Superheat at "D" turbine - degrees F.	54.5	39	42	40	21	21	10	13
Vacuum, inches, based on 30" barometer	26.75	26.38	27.43	27.22	28.0	27.85	28.87	28.75

	4 Hrs. at 140000 SHP	4 Hrs. at 226 RPM	4 Hours at 162 RPM		4 hours at 144 RPM		4 hours at 4500 SHP	
			Z Hr. Water Rate	Z Hr. Fuel Rate	Z Hr. Water Rate	Z Hr. Fuel Cons.	Z Hr. Water Rate	Z Hr. Fuel Cons.
Injection temperature - degrees F.	62	64	64	64	64	64	63	63
Overboard temperature - degrees F.	82	84	82	84	82	82	68	71
* Number of boilers in use.	16	12	5	5	4	4	3	3
Number main turbine-generators in use.	4	2	1	1	1	1	1	1
Number main motors in use.	8	4	4	4	4	4	4	4
Pole combination - main motors.	22	22	44	44	44	44	44	44
Shaft revolutions per minute.	285.9	225.5	162.0	162.1	144.0	144.2	91.0	93.1
Turbine RPM.	1575	1240	1755	1757	1573	1575	1000	1015
Main generator volts, main control board instruments.	4250	3850	4800	4750	3875	3775	1725	1900
Main Generator amperes, main control board instruments, per generator line	4200	4600	3700	3725	3075	3230	1775	1775
Power Factor, main control board instruments.	.88	.87	.645	.645	.65	.66	.64	.63
Indicated KW, main control board instruments.	108000	52800	19600	19600	12400	12800	3500	3500
Disposition of auxiliary exhaust to main turbines.	10th Stg. A-B-C.	10th Stg. C.	None	8th Stg. D.	None.	8th Stg. D.	None	8th Stg. D.

* It should be remembered that these values represent performance with the buckets of the last two stages of the main turbines removed.

COPPERSMITH SHOP.

Cornice brake.
Pipe bending slab.
Shear and punch machine.
Slip roll machine.

BLACKSMITH SHOP.

Three oil burning forges.

AIRPLANE ENGINE OVERHAUL SHOP.

Universal grinder, motor driven.
Universal milling machine, motor driven.
Tool room lathe, motor driven.
2 Sensitive drills, motor driven.
Grinder, motor driven.
Hack saw, motor driven.

SHEET METAL SHOP.

Sheet metal cutter.
Cornice brake.
Shear and punching machine.

EXHAUST TEMPERATURE AS LOAD INDEX FOR OIL ENGINES.

By E. C. Magdeburger, Member.

With the development of oil engines for a wide variety of applications the inadequacy of existing means of measuring their output in service becomes more and more apparent, and a proposal such as was recently advanced by the German engineer, Dr. V. Heidelberg,* to use the easily determinable exhaust temperature as a load index deserves serious consideration.

The only well-known means for measuring the engine output in service is the indicator, although this instrument is not intended to measure the shaft horsepower, in which the operator is primarily interested, but only the power developed within the cylinder and requires the knowledge of mechanical efficiency of the engine mechanism before the indicator card data can be converted into shaft horsepower. Mechanical efficiency varies with the condition of the engine and to rely upon the figure obtained on test must lead to objectionable errors.

Furthermore, to indicate a multi-cylinder engine on all cylinders simultaneously is a big task and after it is done the results are seriously jeopardized by the inevitable difference in the errors of individual instruments, so that the prevalent practice of indicating all the cylinders with one and the same instrument has certain justification behind it.

In high speed engines with small cylinder volume special types of indicators have been developed, requiring expert handling and either producing extremely small diagrams of doubtful value for determining the mean effective pressure by planimetering because of the magnitude of the possible error, or resorting to drawing the diagram point by point and requiring very steady load conditions.

* V. D. I., Dec. 24, 1927, p. 1800.

On the other hand the equal distribution of load in multi-cylinder oil engines, particularly of the type using airless injection of fuel, is easily affected by various factors such as inequality of leakage around the fuel pump plunger and fuel needle, wear of valve gear parts, etc. Thus the need for continuous watch over the cylinder outputs for the purpose of equalizing is imperative, even if the total output of the engine, if determined in some other way, either by means of torque-meter in marine installations or by electrical measurements when driving a generator, does not exceed its normal rating.

Torque meters and torsiograph may also be used for measuring the shaft horsepower of an oil engine, but for small and medium-sized units such means are too complicated and expensive, both in money and time required to properly evaluate their results, whereas, as stated above, the operator ought to know whether or not he is overloading the engine or any of its cylinders at a glance —instantly.

The question might be asked why is such a knowledge of load conditions in the cylinders of an oil engine so important, and the answer to that is—because the oil engine is an internal combustion engine, and as such provides only a given quantity of air per cycle to be used for burning the fuel injected into it. Thus every individual cylinder design has a certain limiting quantity of oil that can be burned with efficiency, and also limiting values for the mean temperatures of all the walls inclosing the combustion space, beyond which these walls develop heat cracks and seizures on one hand and the engine suffers from inefficient fuel combustion with resultant excessive fuel consumption and smoky exhaust on the other. Many different features determine these limits, but as in a chain the weakest link is a measure of its safe application so in an oil engine design it may be the cylinder head, cylinder ports of a two-cycle engine, or quite frequently it is the piston, especially if it is uncooled. Whatever the most vulnerable point may be is of no importance to the operator; suffice it to say that the manufacturer of any given oil engine design is most competent to determine it and prescribe the limiting load, and it is up to the operator to maintain the cylinder load below the given limit if continuous operation is desired.

The problem is comparatively simple for a constant speed engine, but for a variable speed unit such as used for automotive propulsion, dredge pump drive, and in marine service, particularly in submarines where both speed and load may be varied within wide limits the establishment of a real safe limit to engine performance is particularly important. This problem has occupied the attention of the Deutz Company, well known builders of several types of oil engines, and a large number of tests were conducted by Dr. Heidelberg on three different sizes of six-cylinder mechanical injection engines and one four-cylinder two-cycle of crankcase scavenging type.

For purposes of illustration it is sufficient to reproduce (Fig. 1) the results of the smaller six-cylinder four-cycle mechanical injection engine with an individual piston displacement equaling 1.074 cubic feet.

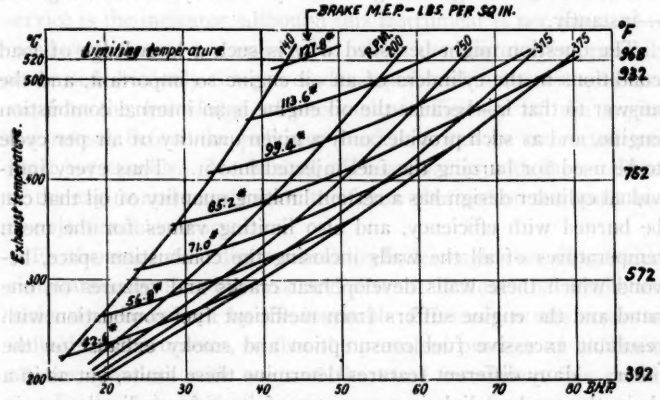


FIGURE 1.—BRAKE HORSEPOWER PER CYLINDER OF 1.074 CUBIC FEET PISTON DISPLACEMENT.

The engine was connected to a water brake to determine the horsepower output, and thermometers of the nitrogen-mercury type were installed in the uncooled elbows as close as possible to the exhaust valves, their mercury bulb projecting into the path of the exhaust gases without any shield whatever. The individual

cylinder outputs were carefully equalized and the mean of the exhaust temperature readings of all cylinders for any given load and speed condition was plotted as ordinate against the horsepower output of the single cylinder. By connecting all these temperature points for a constant speed and again for constant brake mean effective pressure, two sets of curves were received that show exhaust temperature variation with changes in load and for varying speed as shown on the illustration (Fig. 1). These experiments quickly showed that there was a limiting exhaust temperature, and most remarkably the same one for all three different sizes of the same type of engine at which the engines would first smoke, then knock and, after about five minutes running, stop. This same limiting exhaust temperature of 968 degrees F. (520 degrees C.) was developed with widely different brake M.E.P. at different speeds — while at 375 R.P.M. not over 100 pounds per square inch could be developed, at 140 R.P.M. an M.E.P. of 125 pounds per square inch was still harmless. Curiously enough exactly the same limit of exhaust temperature — 968 degrees F. — was obtained when operating these engines on producer gas by increasing the clearance volume and thus reducing compression. Additional checking of the results on numerous engines on test gave figures within $\pm$ 5 per cent of those shown on Fig. 1. Variation of cooling water discharge temperature from 122 degrees F. to 158 degrees F. did not affect the exhaust temperature appreciably. Standard piston clearance which experience has developed can be varied but very little since it must be small enough to permit idling or light load without blowing by the piston rings and excessive knocking, and large enough so that 20 per cent overload can be carried without piston seizures.

The two-cycle engines of the crank case scavenging type using injection chamber for fuel atomization and having also non-cooled pistons gave 716 degrees F. as their limiting temperature.

The temperature curves for constant R.P.M. are slightly curved for four-cycle engines (Fig. 1) and considerably more curved for the two-cycle type investigated, showing that heat load rises faster than useful load developed. Furthermore, these curves show that the maximum safe useful load does not vary proportionally to the

engine speed, but that the heat load increases much faster with the speed. Thus the exhaust temperature limit gives the limits for both engine speed and brake M.E.P. and thereby determines maximum horsepower output of the engine, which may be developed safely. The normal rating of the engine must naturally be correspondingly reduced.

The exhaust temperature limit is particularly important when excess air, which is now usually taken at 20 per cent for most engines with rationally designed combustion spaces, is reduced and exhaust temperature rises very quickly.

For larger engines it was found that the maximum safe brake M.E.P. would diminish rapidly, and for the type of engine investigated with uncooled pistons 193 B.H.P. was the maximum that could be developed since any further increase in cylinder would be compensated by reduction in M.E.P.

Thus it is proposed by Dr. Heidelberg that every engine leaving builders' works be furnished with a set of curves similar to that shown so that from observing the individual exhaust temperatures of each cylinder which can be done very quickly with suitably installed pyrometers, the operator may easily determine

(*a*) the total shaft horsepower developed at any engine speed,

(*b*) the distribution of load on individual cylinders,

(*c*) whether the load distribution, even if unequal, is dangerous to any of the cylinders,

(*d*) maximum possible horsepower output at any engine speed,

(*e*) maximum engine speed for any desired torque or M.E.P. or maximum M.E.P. for any desired engine speed,

(*f*) best operating conditions with least heat load when both engine speed and brake M.E.P. may be varied.

DISCUSSION

MARINE DEVELOPMENT OF PULVERIZED FUEL.

DISCUSSION BY REAR ADMIRAL C. W. DYSON, U.S.N., RETIRED.

When the paper by Mr. Jefferson and Commander Evans was read at the annual meeting of the Society of Naval Architects and Marine Engineers in the Fall of 1927, I listened with the greatest amount of interest. I have read the present paper with the same amount of interest.

Notwithstanding the interest with which I have both listened and read, at the end I have experienced a feeling of both bitter disappointment and injustice. I have gathered from the two papers that the authors have become obsessed with that part of the field of accomplishment in which they, themselves, were actually engaged, and have failed to thoroughly scan the other parts of the field in order to ascertain the direct cause of the success obtained and therefore, on account of this neglect, have not given the proper amount of credit due those to whom the success is directly attributable.

The tests described were carried out in an extremely thorough manner, and the difficulties encountered in properly pulverizing the fuel and bringing the dust to the burners were more or less successfully overcome. For this Mr. Jefferson, Commander Evans and their associates are deserving of the highest honor, and it is not my desire to detract one particle from this honor.

However, the great sea of accomplishment has completely submerged the true hero of the exploit, the burner, for without this burner success could not, at that time, have been achieved.

For many years crushers, pulverizers and distributors have existed and have been used for the preparation and distribution of fuel to burners. Pulverized fuel burners have also been in use for a long time but of those in use there was not one which did

not throw an extremely long flame which required furnaces of enormous volume. Not one of them could be used to turn pulverized fuel in the small furnaces of a marine Scotch boiler.

The successful outcome of these tests I regard as marking an epoch in Marine Engineering, as great an epoch, in fact, as was marked by the invention of the Diesel Engine. While the invention of the latter apparently condemned to the scrap heap steam engines of moderate powers, the invention of the Peabody Pulverized Fuel Burner took these same steam engines and has placed them in a position where they can successfully compete with the Diesel.

The invention and development of this burner are of such importance that we who are responsible for it can not afford to allow their importance to be drowned in a sea of data in which everything except the results obtained is treated as being merely incidental.

I say *we* with a great deal of emphasis, as I personally in the Spring of 1922, in looking into the future foresaw the time when the price of oil fuel would be so high as to cause users to look around for a cheaper fuel and a means to change to it at the minimum expense.

Following out this line of thought I invented and patented a burner to which the present mechanical atomizing oil burners could be converted at very little cost. It made use of the whirling air principle to whirl the pulverized fuel and throw it out into a cone with very thin fuel walls which could be easily penetrated by the air streams. With it pulverized fuel could be burned alone; it could be burned in combination with oil fuel, the cones of the two fuels intermingling in the furnace; oil fuel could be burned alone.

The original sketches were shown to persons high in authority, both in and out of the Naval Service, but these gentlemen were unable to see any distance into the future and therefore gave scant encouragement. Finally, these sketches were shown to Mr. E. H. Peabody, President of the Peabody Engineering Corporation, who immediately grasped the possibilities and offered to pay for the cost of the patent provided that his company should have the first opportunity of purchasing the patent. This was agreed to; the patent was allowed and was sold to Mr. Peabody's Company.

In developing the burner the pulverized fuel inlet was moved in close to the outlet of the tuyère, it having been close to the tuyère inlet originally, and was fed through an involute passage through a circumferential slot in the tuyère wall. This change was a decided improvement as it destroyed any possibility of the tuyère becoming filled with flame.

This burner has been successful from its very first application and when tested for marine purposes has marked an epoch in marine progress.

When any invention and its development are followed by epoch-making results, those responsible for the invention and its development are entitled to a proper amount of honor and credit. As the historians of these tests have, up to date, neglected to give such honor and credit, it is my painful and embarrassing duty to claim them as a portion of the heritages which we, the inventor and the developer, shall hand down to our children and our children's children.

NOTES.

COMPARISON OF TURBO-ELECTRIC AND DIESEL DRIVE IN LARGE PASSENGER SHIPS.

By Dr. W. L. R. Emmet.

In "The Motor Ship" for March, a discussion of turbo-electric *versus* Diesel drive appears, which is based upon reports of a talk which I recently gave to the Propeller Club in New York. This article compares a reported fuel oil consumption of 0.8 pound per S.H.P.-hour of the new *California*, with 0.4 pound in a Diesel ship, and states:—

"In other words, the amount of oil used on the most modern and efficient turbo-electric liner is approximately double that required for a motorship of the same size and power."

Since similar numerical comparisons have often been made, and are grossly misleading, it seems desirable that an approximately true relation evaluation should be drawn, and the best basis for this which I have been able to find is a comparison between the *California* and the *Gripsholm*, of the Swedish-American Line.

The *Gripsholm* has a displacement of 23,600 tons, and is operated at about 16 knots, while the *California* has 30,250 tons displacement and her normal full speed is 18 knots. I will compare the performance of the two ships when operating at 16 knots, which is unfavorable to the *California* since she must use two generating units lightly loaded at a speed above about 15.5 knots.

At 16 knots, the fuel consumption per day of the *Gripsholm* is 61 tons of fuel oil and 1 ton of lubricating oil, which, since lubricating oil costs eight times as much as fuel oil, may be considered as the equivalent of 69 tons of fuel. The *California* uses 106 tons of fuel and no appreciable quantity of lubricating oil.

These consumptions are for all purposes and, since the *California* cooks by electricity and refrigerates a large cargo of fruit through two-thirds of her round trip, the all-purpose comparison is in no way favorable to her.

Thus the fuel consumptions in pounds per ton-mile are:—

California	0.0211 pound
Gripsholm	0.01715 pound

An operator of many Diesel ships and steamers in a very recent large contract paid at New York for Diesel oil $15 per ton, and for oil burned in their steamers $10.20 per ton. The prices per 1000 ton-mile are, therefore: *California*, $0.096; *Gripsholm*, $0.1145. The *Gripsholm* is, however, entitled to a credit here since the larger ship drives more easily per ton. This correction brings the comparison to *California*, $0.096; *Gripsholm*, $0.106 oil cost per 1000 ton-miles (displacement tons).

The difference in cost of machinery between the *Gripsholm* and a similar ship with turbo-electric drive is not known, but, on the basis of comparison

of Diesel and geared turbine ships given by Sir John H. Biles in "Engineering," June, 1926, it would be about $250,000 in favor of the turbo-electric ship. The value of this saving, if considered on a 10 per cent basis, is equivalent to about 10 per cent of the annual fuel bill. There would also be an appreciable saving of weight.

The third liner, which is being built for the I. M. M. Company, has 75 pounds higher steam pressure and 150 degrees more superheat than the *California*, and, with equally good turbines, her propulsion should be 10 per cent more efficient.

Thus, instead of being half as good as "The Motor Ship" suggests, the above just comparisons show that on this fuel price basis a good turbo-electric ship of the type planned for the third I. M. M. vessel might have advantages equivalent to a fuel saving of about 28 per cent. And, even if both burned the same kind of fuel, they would be not much more than equalized.

But the *California* has many other advantages. Her machinery involves no motion other than simple rotation. She is completely free from noise or vibration at all speeds. She can make 15.5 knots with half her machinery idle. There is practically nothing which could happen to her machinery which, with a few spare parts, could not be repaired at sea.

The part of this argument which will be most subject to question is the matter of Diesel oil price. I know that some of the advocates of Diesel engines say that they can burn anything, and these relative prices may be very different in other parts of the world. My figures are based upon actual prices in very large quantities, and I am informed that since these purchases another large firm has paid $16.20 per ton for Diesel oil instead of the $15 which I have considered. There will always be a difference between desirable Diesel oil and oil for steam making, and my claim is that, even without an advantage in oil price, the well-designed turbo-electric ship of this type is justified.

There is one condition which may greatly influence the uses of electric drive, namely, that its adoption takes the building of machinery away from shipbuilders. Shipbuilders have frequently discriminated against it in making ship prices and this has been the main cause of its delay. It is hoped that the performances of the *California* and other large ships now building will do much to overcome this impediment.—"Shipbuilding and Shipping Record," May 31, 1928.

THE FOUR-DAY LINERS.

Certainly no private proposal of recent years has aroused more curiosity or provoked more discussion than the plan made public last year of running a line of daily four-day liners between America and Europe.

Some months ago this paper, in commenting editorially upon the matter, expressed the opinion that although the scheme, from an engineering point of view, was doubtless practicable, the enormous amount of money needed in order to materialize it would be prohibitive, or at any rate would involve government backing and support on an unprecedented scale.

Since that time much has happened. Apparently it has been brought home to the promoters of the proposed line that, in order to maintain an average sea speed of from 32 to 35 knots, much larger ships would be needed than were at first anticipated. It has followed that the tentative sailing schedule has been cut in half—departures to be made every other instead of every day. The size of the ships has been greatly increased, and

their number reduced—we believe from 10 to 6. Incidentally, this is in line with a suggestion in the editorial above referred to.

Furthermore, and most important, a shipping bill has become law which makes available large sums of money, at low interest rates, for the building of privately owned American vessels.

Thus, on two counts, at any rate, the four-day liners are nearer realization—a more practicable sailing schedule has been adopted and Government aid on a large scale has been made available. Notwithstanding these facts, the Shipping Board has submitted to the Senate an adverse report on the proposal.

While the board's report may have been somewhat of a surprise to many people, there having been, apparently, a somewhat widespread feeling that the scheme was "going through," it appears that in view of the character of the evidence and material submitted to it, the board did not feel that it could, conscientiously, come to any other decision.

Following what cannot be considered otherwise than a very wise line of action, one which should have produced convincing results, the promoters of the proposed line had submitted to committees of experts the various phases of their scheme, naval architecture, engineering, economics and finances. The members of these committees were well and favorably known in this country; they were men of established reputations in their respective lines of business. Summaries of these several reports were combined in a pamphlet which, as we understand it, while not giving all the details of each report, gave its essence. While the board was undoubtedly furnished with the details, the pamphlet gives in fair outline the basis of the proposal upon which the board was requested, by the Senate, to express its opinion.

A somewhat similar line of action was followed in the building of the *Mauretania* and *Lusitania*. With both the Cunard ships and the great liners now under consideration, past experience could furnish but an imperfect guide for the designers—they were reaching out into almost unknown and little explored territory; and in order to insure success in meeting the unprecedented conditions imposed upon them, they had to develop to the utmost every possible source of knowledge bearing upon their problems, every line of scientific investigation which might throw light upon the uncertain path ahead of them. With the British ships, all this was done; no stone was left unturned; with a result which was, without doubt, one of the greatest engineering achievements of all time.

The promoters of the four-day ships have made a start in the right direction—they have submitted their problem to experts of unquestioned ability; but the results so far made public are not convincing, and one cannot but feel that until the technical and engineering features of the undertaking are in a far more advanced stage than apparently exists at present, the Shipping Board could follow no other course than to withhold judgment until evidences of scientific study and investigation, comparable with that which preceded the building of the great Cunard liners, are placed before them. Lacking this, the board would appear to have no other course than to disapprove the proposition as submitted.

The financial and economic reports, which are included in the promoters' statement, may be passed over until the proposal takes more concrete form. It appears, however, that the estimated cost of construction is rather on the low side, particularly in view of the probability that the ships, if built, will very likely have to be somewhat larger than at present contemplated.

Given 35-knot vessels, it would appear that the schedule of sailings as laid out by the committee on operation is practicable and could be carried out, although the board does not concur in this view.

In the field of naval architecture, considerable of a technical nature has evidently been accomplished. The development of the hull design has made clear the importance of length, at least, if not of absolute size, in maintaining the unusually high speed. One very considerable increase has already been decided upon, and it would not be surprising if a further addition in length would be made, before the final and satisfactory design dimensions are arrived at.

So far as hull weight is concerned, it is not apparent that any radical reduction from previous practice in transatlantic liners could very safely be indulged in. High tensile material can be made to save weight, where tensile stress alone has to be met; and it was extensively made use of in building the *Mauretania*. Unfortunately, however, long high-powered ships suffer quite as much from sagging as from hogging strains, and the deck compression resulting from the former can be met no better by high tensile than by ordinary ship steel—only sectional area of material, with its accompanying weight, can take care of this condition.

In view of the fact that these ships will have to be driven far harder than any at present in service, it would appear that structurally they must be at least equal in strength to the best of their predecessors; and such details of equipment and fittings as are directly exposed to wind and wave must be even more robust than what is now considered safe and satisfactory.

So far as accommodation plans are concerned, while important, they appear a somewhat secondary matter at this stage of the proceedings. In this respect, the Shipping Board's criticism of the promoters' plans appears somewhat premature, and although their points may have been well taken, they would best have been omitted from the report to the Senate, because, in comparison with the other matters discussed, they are trivial and altogether susceptible of satisfactory adjustment at a later stage of the development.

By all means the most important and—to many of those who have seen it—the least satisfactory portion of the prospectus is that devoted to engineering.

The problem presented by the propelling machinery, first in the selection of type, and second in detail design, is by far the most important which has to be met in the design of these vessels; and, when one learns that the type of machinery is not yet even settled, further comment seems rather superfluous. Whatever the type, the weight alloted to machinery is apparently such that a close approach to what is generally known as naval practice will be necessary, and it is an open question how far this type of propelling machinery and auxiliaries can be modified to meet the requirements of transatlantic service without a material increase in weight.

One cannot but feel that as the design of these vessels is developed in all its details, the necessity of great strength and ruggedness of both hull and machinery will demand more weight and a larger ship than has as yet been proposed. The building of four-day ships is quite possible so far as the technical and engineering side is concerned, but to maintain such a schedule will require ships of enormous size and cost. The commercial success of such an undertaking is at best, problematical; but more than commercial success is involved in the project. For many reasons, it is likely that the Government will lend a helping hand, once it is convinced that a firm technical basis of design has been established, and that a large and definite amount of private capital is actually available; but until the scheme has reached a greater degree of "crystallization" than is yet apparent, it is unlikely that the Shipping Board will feel justified in giving the proposal its unqualified approval.—"Marine Engineering, and Shipping Age," July, 1928.

THE *KING GEORGE V*, THE *MERCER*, AND THE PANAMA PACIFIC LINER *CALIFORNIA*.

By Capt. S. M. Robinson.

For many years the Diesel engine struggled against what seemed to be insuperable handicaps. In spite of the very promising theoretical cycle of this engine, it was a long time before any of the advantages materialized. Unreliability was the most difficult handicap to overcome and after this had been conquered there still remained, for marine purposes, the disadvantages of excessive weight and first cost. But in recent years, all these difficulties have been overcome and, when it started, progress was so phenomenally rapid that it caught steam engineers totally unprepared for such competition. Since the World War, the installation of Diesel engines in ships has been increasing at such a rate that most of the steam engine builders have given up the fight and started to building Diesel engines and, until very recently, it looked as if steam engines and boilers were doomed to be swept from the sea. But such conditions always bring about vigorous effort on the part of the opposition and this case has proved to be no exception to the rule.

To show the tendency in commercial marine engineering, the three ships named in the subject have been used as examples. They constitute three separate and independent experiments and yet they are very closely related as will now be shown. Although all of these ships have been thoroughly described, it is believed that it will be best to review them briefly and, therefore, a short resume of their principal characteristics is given here.

The *King George V* was built by Wm. Denny & Bros., with the cooperation of the Parsons Marine Steam Turbine Company in 1926. This was the first ship to use high pressure and high temperature steam. She is a small excursion steamer of 260 feet in length, 32 feet in breadth, and draws 11 feet. She is designed for a steam pressure of 450 to 550 pounds per square inch, and a steam temperature of 750 to 800 degrees F., giving roughly about 250 degrees F. of superheat. The total horsepower developed on two shafts is 3500 S.H.P. Her boilers are Yarrow Marine type coal-burning boilers and are fitted with air preheaters and steam superheaters. On trials a stack temperature of 616 degrees F. was obtained which compare favorably with present stack temperatures in low-pressure boilers. An economy of 1.085 pounds of coal per S.H.P. was obtained. The water-rate of the main turbines was 8.01 pounds of water per S.H.P. hour. The results of these trials may be taken to demonstrate conclusively that high pressure and high temperature steam can be handled successfully in marine installations. Being a very humble beginning, the results achieved were not so good as those obtained on shore where the same pressure and temperature are employed.

The *Mercer* is a Shipping Board vessel built in 1919. She is 395 feet 6 inches long, 55 feet beam, and draws 27 feet with a deadweight of 9730 tons. Originally, she was equipped with three single-ended, three-furnace, oil-burning Scotch boilers and a General Electric geared turbine of 2500 S.H.P. on a single screw. The designed speed of the vessel was 10½ knots. The vessel was converted to a pulverized coal burner in 1927. The burners were furnished by the Peabody Engineering Corporation and are of the combined coal and oil burning type. The development of this burner made this experiment possible and the greatest credit is due to Mr. E. H. Peabody, who is one of the world's most prominent combustion engineers. The pulverizers are of the ball type and were furnished by the Kennedy-Van Saun Engineering and Mfg. Company. The coal is handled by con-

veyors (furnished by the Link Belt Company). Single roll crushers (built by the Jeffries Crusher Company) reduce coal to 1¼-inch grains and it is then discharged to ready "bins," from which it is fed by gravity to the pulverizers. The coal is drawn from the pulverizers by Sturtevant fans and is fed to the burners. The vessel has made successful voyages and has been maneuvered in port, using powdered fuel only. The apparatus is still somewhat in an experimental state and, therefore, no figures of comparative fuel economy are available, but the performance has been stated to be entirely satisfactory. This experiment has been carried out jointly by Mr. C. J. Jefferson of the Shipping Board and Commander J. S. Evans of the Fuel Oil Testing Plant. Extensive experiments with various types of crushers, pulverizers, and burners were carried out at the Navy Fuel Oil Testing Plant at Philadelphia. As a result of these, the ship was equipped with an experimental installation. Preliminary trials were then run and these proved so successful that the ship was put on a regular run, and is still going successfully. While fuel measurements are not yet available, the experiment can be considered successful for there can be no question of satisfactory economy, if the apparatus can be made to function. The results obtained on shore have been so conclusive as to leave no doubts on that score.

Both the *King George V* and the *Mercer* may be regarded as attempts to introduce the best shore steam engineering into ships and, regarded in that light, they were highly successful.

The third ship, the *California*, is in a somewhat different category from the first two ships. In this case, there were certain definite marine problems to be solved and, while power-station practice was taken advantage of to some extent, in the main, the solution involves either new methods or new applications of old ones. The *California* is the first electrically propelled, large, passenger vessel. She is 601 feet long, 80 feet beam, 32 feet 3 inches draft, and has a loaded displacement of 30,250 tons. She develops normally 13,500 S.H.P. and has a maximum of 17,000 S.H.P. Her normal speed is 16.5 knots and her designed maximum speed is 18 knots. She is equipped with 12 oil-burning Babcock & Wilcox boilers of 55,176 square feet of heating surface and 16,000 square feet of superheating surface, giving about 200 degrees superheat. The turbines, generators, motors, and the remainder of the propelling equipment are of General Electric Company design. The motors are of the synchronous-induction type which has been developed entirely as a result of using electricity for propelling ships. The generators have a maximum speed of 2880 R.P.M., giving the motors a speed of 120 R.P.M. This ship had a very successful trial and has completed her first voyage which was also quite satisfactory and showed a fuel consumption of .8 pound of oil per S.H.P. for all purposes, which is very creditable, indeed, when the large number of auxiliary steam users is taken into account.

Now what do we have when we combine the results of the trials of these three ships? They show that it is quite possible to use all the best parts of the present practice of power stations, using powdered coal as fuel and generating steam at high pressures and temperatures. Electric propulsion will make it possible to place the generators in the fire rooms alongside the boilers so there will be very little steam piping used and thus the difficulty of providing slip joints will be solved by doing away with the necessity for them. It will be perfectly safe to place the generators in the firerooms, even if coal dust is present, as the generators can be totally enclosed and made self-ventilating with the air cooled by water circulation. Power transmission will be by electric cables instead of steam pipes and the turbines will be non-reversing. Some of these shore stations are developing a kilo-

watt of electricity at the switchboard for .9 pound of coal, a truly remarkable performance. Of course, this figure is beyond the reach of any marine installation that could be made at the present time, but it could be approached very closely by applying power station practice as indicated. This must be compared with a Diesel consumption of .4 of a pound of oil per S.H.P. Naturally, the comparison of these two figures is dependent on the values assumed as the price of coal and oil respectively, and this immediately brings up the question of what run the ship is to be designed for. In any case, however, it will be seen that the race between the Diesel engine and the steam turbine is by no means finished. Doubtless, there is and will continue to be a field for both and the competition between them will insure the continued rapid development of both."—"Marine Journal," May, 1928.

THE BOILER EXPLOSION ON THE *KING GEORGE V.**

Abstract of Official Report Concerning an Explosion In One of the High-Pressure Water-Tube Boilers of the Famous Clyde Pleasure Steamer.

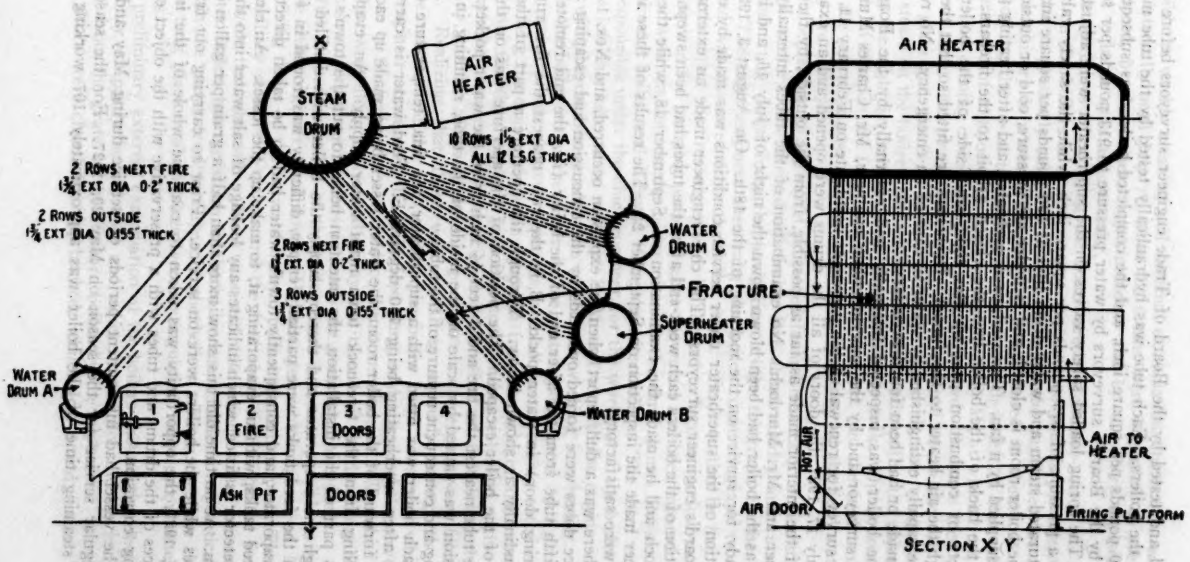
In view of the great attention which marine engineers are now giving to the subject of high-pressure, high-temperature steam installations, the issue of a report dealing with an official inquiry into the cause of a boiler explosion which occurred some six months ago on the pioneer high-pressure turbine steamer *King George V*, owned by Turbine Steamers Limited, Glasgow, is of great interest. The explosion occurred about midday on September 29 last, as the vessel was approaching Irvine Bar preparatory to entering the harbor. Unfortunately, the accident was attended by loss of life; James Bryson and Edward Kane, both firemen, were severely scalded and subsequently died at Kilmarnock Infirmary from shock due to scalding. Edward Kane died on September 29 at 8 P. M., and James Bryson on September 30 at 1:10 A. M.

The Board of Trade report says:—

"The boiler from which this explosion took place is the forward one of two coal-fired Yarrow patent high-pressure water-tube boilers, built in 1926 by Yarrow & Co., Ltd. It consists of a forged steel steam and water drum 11 feet long over the ends and 3 feet 6 inches internal diameter. This is connected to three forged steel water drums by means of straight tubes which are expanded and bell-mouthed into the drums. Each of these three water drums is 18 inches internal diameter. The fire grate is situated between the nests of tubes connecting the saturated steam and water drum to the two lower water drums. A Yarrow superheater is placed between the two water drums on the right-hand side of the boiler. The generating surface of the boiler is 2550 square feet, while that of the superheater is 870 square feet. The usual necessary mountings are fitted, a stop valve and safety valves being placed on the superheater drum, while the automatic and hand-feed regulating valves, auxiliary stop valves, sentinel safety valve, and water gauges are fitted on the saturated steam and water drum.

"The sizes of the tubes connecting the saturated steam and water drum to the water drums are as shown on the drawing below. These tubes are of solid drawn steel, cold finished, and were made by The Perfecta Seamless Steel Tube and Conduit Co. (1923) Ltd., Birmingham. They were in-

* Boiler Explosions Acts, 1882 and 1890, Report of Board of Trade Preliminary Inquiry, No. 2900.



Front Elevation and Sectional Side Elevation of Yarrow Boiler, showing Location of Fractured Tube.

NOTES.

spected and tested by the Board of Trade engineer surveyors before being put in the boilers. Each tube was hydraulically tested by the tube makers to 1500 pounds per square inch, and the completed boiler was subsequently tested by the Board's surveyors by water pressure to 913 pounds per square inch. The spring loaded safety valves on the superheater were adjusted to lift at a pressure of 575 pounds per square inch, while the safety valve on the saturated steam and water drum lifts at 590 pounds per square inch.

"The boiler room is closed, and is under air pressure, cold or outside air being supplied by a fan. This cool air is preheated, and after heating passes down the back of the boiler into the closed ashpit to the firebars. The products of combustion pass up the right-hand side of the boiler and through the air heater to the funnel. Drenchers are fitted so that the fires may be rapidly extinguished by water in case of an emergency. No repairs were made or had been found necessary.

"The boiler was inspected internally and externally by the Board of Trade surveyor and by the superintending engineer, Mr. Charles Murdoch, at the survey for renewal of the passenger certificate on February 11, 1927. On July 17, 1927, the doors of all the drums were opened and an examination of the interior made as far as possible, from the outside, by the chief engineer and Mr. Murdoch. No examination of the tubes internally was made as the boiler had been blown down the night of July 16, and had to be ready for service on the morning of the 18th. On August 3, 1927, an inspection of the superheater under service conditions was made by one of the Board's engineer surveyors. The chief engineer made an external examination of the boilers each week-end after the tubes had been swept. Mr. Murdoch and he made the examination on September 18, while the chief engineer made the inspection on September 25. The results of these inspections were satisfactory.

"There was a dull report when the explosion occurred, and Nos. 1 and 2 furnace doors were forced outwards by the concussion and escaping steam. The fifth tube from the after end of the boiler (*i.e.*, the end remote from the firing door) in water pocket B in the row nearest the fire ruptured longitudinally as shown below. Through the aperture a part of the contents of the boiler escaped. The position of the aperture was on the side of the tube nearest the fire and 3 feet ½ inch from the water pocket. The explosion was caused by scale on the inside of the tube, resulting in overheating and consequent rupture of the tube.

"Each boiler was fitted with a superheater, the final temperature of the steam after superheating being 750 degrees F. Feed water is carried in tanks forward of the boiler room, the water losses being made up each day by filling from the Greenock town main water supply. An evaporator forms part of the installation, the intention being to put the town's water through the evaporator and thereby supply the boiler with distilled water. When the feed tanks were partially empty, difficulty was found in feeding the evaporator, and consequently town's water had to be taken direct from the feed tanks, without evaporating it, to make up the losses. An electrical salt detector is fitted, which indicates any leakage of salt water into the feed system. At no time did this show more than half a grain per gallon of impurities while the boilers were on service. Prior to carrying out trials in April, 1927, the opportunity was taken to coat the whole of the internal surfaces of the drums and tubes with a preservative with the object of preventing corrosion.

"The vessel had intermittent periods of service during May and went on regular service for the season on May 23, 1927. For the season the total steaming time of the boiler was approximately 107 working days.

Beyond the weekly cleaning and external examination, the boilers were not seen internally until July 17, when the drums were inspected, as previously mentioned, by the owners' superintendent and by the chief engineer, and found to be in satisfactory order.

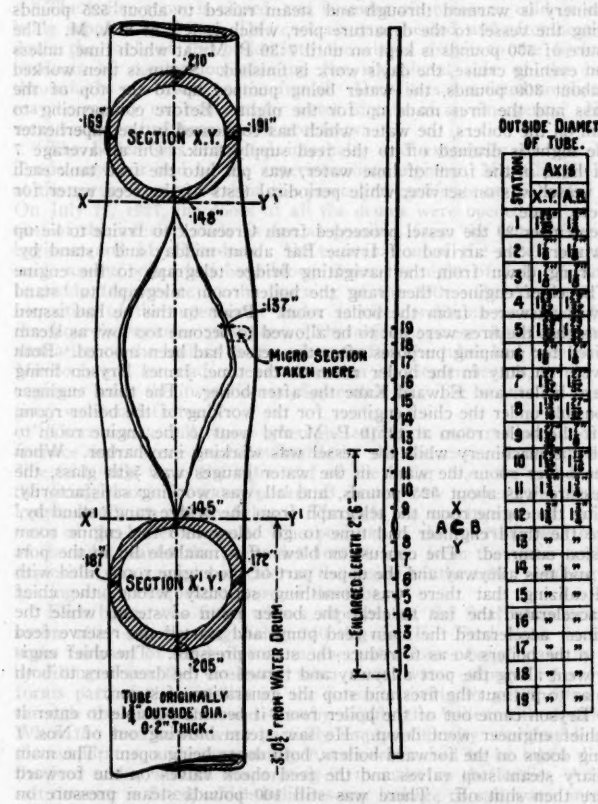
The conditions of working the boiler are as follows:—At 5 A. M. the steam on the boilers is at a pressure of about 200 pounds per square inch, and this is gradually raised to 350 pounds when the auxiliaries are started. The machinery is warmed through and steam raised to about 525 pounds for working the vessel to the departure pier, which is left at 8 A. M. The full pressure of 550 pounds is kept on until 7:30 P. M., at which time, unless there is an evening cruise, the day's work is finished. Steam is then worked back to about 300 pounds, the water being pumped up to the top of the gauge glass and the fires made up for the night. Before commencing to raise steam on the boilers, the water which has condensed in the superheater during the night is drained off to the feed supply tank. On an average 7 pounds of lime, in the form of lime water, was put into the feed tank each week the vessel was on service, while periodical tests of the feed water for acidity were made.

"On September 29 the vessel proceeded from Greenock to Irvine to lie up for the winter. She arrived off Irvine Bar about midday and 'stand by' had been rung down from the navigating bridge telegraph to the engine room. The chief engineer then rang the boiler room telegraph to 'stand by,' and was answered from the boiler room. Prior to this he had issued instructions that the fires were not to be allowed to become too low, as steam was required for pumping purposes after the vessel had been moored. Both firemen were on duty in the boiler room at the time, James Bryson firing the forward boiler, and Edward Kane the after boiler. The third engineer was responsible under the chief engineer for the working of the boiler room, and he left the boiler room at 12:10 P. M. and went to the engine room to assist with the machinery while the vessel was working into harbor. When he left the boiler room the water in the water gauges was ⅝th glass, the steam pressure was about 525 pounds, and all was working satisfactorily. On reaching the engine room the telegraph from the bridge rang 'stand by,' but before the third engineer had time to go below into the engine room the explosion occurred. The concussion blew off a manhole lid in the port alleyway, and this alleyway and the upper part of the engine room filled with steam. Realizing that there was something seriously wrong, the chief engineer accelerated the fan to clear the boiler room of steam, while the third engineer accelerated the main feed pump and started the reserve feed pump on to the boilers so as to reduce the steam pressure. The chief engineer then went along the port alleyway and turned on the drenchers to both boilers so as to put out the fires and stop the generation of steam.

"After Bryson came out of the boiler room it became possible to enter it and the chief engineer went down. He saw steam blowing out of Nos. 1 and 2 firing doors on the forward boilers, both doors being open. The main and auxiliary steam stop valves and the feed check valves on the forward boiler were then shut off. There was still 100 pounds steam pressure on the after boiler, but the steam in the boiler room made it impracticable to ascertain the water level in either of the boilers. From the time the explosion took place until the fires were extinguished was approximately six minutes.

"A preliminary external examination of the boilers showed that there was a quantity of partly burned coal and ashes on the floor which had been ejected from the grate of the forward boiler by the explosion. Nos. 1 and 2 fire doors were closed but not latched, while Nos. 3 and 4 doors were

closed and securely latched. A firing shovel had been found lying beside No. 1 door. These doors are so hinged as to be self-closing. Catches are also fitted so that in the event of a tube bursting the doors could not be forced open. It was part of the ordinary routine to latch each door after the coaling of that particular fire had been completed. When the fireman on No. 1 boiler was firing, the fireman on No. 2 boiler assisted him by opening



Sketch showing Extent of Rupture.

and closing the furnace door as each shovelful of coal was put in. This ensured the door being open for the shortest possible time. No. 1 door closed and latched properly, while No. 2 door closed but the door would not shut close enough to allow the latch to engage in the catch. It is stated that when the vessel left Greenock all the doors were in good condition and could be properly latched.

"On going inside the furnace, it was found that the fifth tube from the after end of the boiler connecting the steam drum to water drum B and in the row next the fire had ruptured longitudinally. The opening was in such a direction as to discharge the steam and water across the grate, the extent of the rupture being 4⅜ inches long and 1 9-16 inches maximum width. This tube had been forced back by the explosion against the tubes in the second row. The sixth tube in the first row was slightly bulged in two places, while a number of the tubes at the after end of the row dropped towards the fire. The fire in way of Nos. 3 and 4 doors was practically bare of coal or cinders.

"An internal examination of the boiler was subsequently made. There was a considerable amount of soft scale on the water side of the fire row of tubes connecting the steam drum to water drum B. This varied in thickness, there being more deposit on the tubes at the after end of the row. The deposit was not uniformly thick over the internal surface of the tubes, being much thicker on the side of the tubes nearest the fire. At the back end of the fire row the thickness averaged ⅛ inch, which gradually decreased to 1-16 inch at the front end of the same row. Attached to this deposit were pieces of scale which appeared to have been loosened from the heating surface at some previous time and to have become attached to the scale which subsequently formed on the tubes. Row 2 in the same bank of tubes had only a very slight deposit of scale, while rows 3, 4 and 5 were clean. The two fire rows form the most effective part of the heating surface in the boiler, and the heaviest deposit might be expected here, but as the deposit was thickest at the back end of the fire row, further inquiry was made. It appears that in order to keep the fire of even thickness, more coal had to be put on the back end of the furnace, and consequently evaporation, and therefore scale deposit, would be greater at the back end. It follows that risk of overheating would be greater at that end of the fire row. This was borne out by the quantity of deposit inside the tubes and by their external appearance. The tubes connecting water drums A and C to the steam drum were free from any deposit apart from the preservative which had been used at the commencement of the season.

"With regard to the tube which ruptured, most of the deposit on this was removed by the rush of water and steam, but there was a small amount left at the parts remote from the rupture. This tube was enlarged over a length of 2 feet 6 inches, which length was in the zone of the flame and gases on their way to the uptake. The tube was measured at intervals of 3 inches over a portion of the length, and the measurements, as well as sections showing the thickness of the tube at each end of the fracture, are given in the drawing on the previous page. These sections show that the tube had increased in diameter and that the consequent thinning of the tube wall had taken place at the side exposed to the furnace, *i.e.*, where the scale was thickest. In cases of tubes which burst due to overheating, the fracture is generally drawn away to a fine edge, whereas in this case the fracture was short and the material, although below the original thickness, was not drawn out. Ordinary cases of overheating also take the form of a local bulge, whereas in this case the tube had enlarged over a considerable length.

"Where overheating and ultimate rupture is caused by deposition of scale, such overheating must occur more than once as when a tube overheats the first time expansion and consequent thinning takes place. This expansion throws off the scale, thus allowing water to get in contact with the tube and cool it. Further overheating will not occur until a sufficient thickness of scale again forms. In this case the tube has expanded over a considerable length and this expansion must have taken place previ-

ously in one or more stages. Subsequent local overheating due to an excessive accumulation of scale at this point caused the tube to bulge and finally fracture. That the overheating had taken place on more than one occasion is indicated by the portions of thick scale which were found to adhere to scale which had formed at a later period. It has been previously stated that the back end of the boiler had to be more heavily fired than the front end in order to maintain an even thickness of fire. Should the fire become thin, the flame at this part would be intensely hot with the result that there would be localized overheating. This, coupled with the presence of scale in the tubes, would account for the thinning of the tube. That the temperature of the material of the tube was at least 1000 degrees C. was shown by a micro section taken from the fractured edge. This showed a structure associated with quenching from high temperatures. At such temperatures the tenacity and elasticity of the material would be so reduced that the tube could not withstand the pressure and therefore fractured. The row of tubes nearest the fire in water drum B is being renewed. Steps are also being taken to supply the boilers with pure distilled water only, and the use of lime is to be discontinued."

"It is essential that, to avoid corrosion and fouling of the heating surfaces by scale, the feed water should be pure. In seagoing steamships, if there were no loss of feed water by leakage, the question of scale would present little difficulty. Unfortunately there are always losses, and in the present case water obtained from town mains was used to supplement the feed from the condensers. The water was presumably of good quality but hard, and no other treatment was considered necessary than the mixing of lime with the feed water. With boilers of the ordinary marine or Scotch type no exception could reasonably be taken to the methods used in dealing with the feed water, as in such boilers a proportion of the soluble matter in the feed water would probably have been precipitated to the comparatively quiescent water at the bottom of the boiler, and any scale formed would have been distributed more or less uniformly over the heating surfaces. In a water-tube boiler, especially in one of a small tube type, the water is in continual and rapid movement so that there is less chance of solid matter being deposited as sludge; also owing to the heavy evaporation in the tubes near the fire, a large proportion of the scale is formed in those tubes, and even when the feed water is, when judged by old standards, comparatively pure, a thick layer of scale may be rapidly formed, causing overheating and distortion. It is clear, therefore, that only distilled water should be used in high-pressure water-tube boilers, and in this vessel an evaporator was fitted, so that the desirable degree of purity could have been obtained by distillation of the town water. Such boilers should not be closed up after cleaning before it has been ascertained by inspection that every tube is clear and perfectly clean.

"Unfortunately in this case the tube failed while a fire door was open and two firemen were directly exposed to the explosion. The engineers acted with promptitude and apparently did all that was possible in difficult circumstances. The owners are now arranging for the use of distilled water only for feed make-up."—"The Marine Engineer and Motorship Builder," May, 1928.

NAVIGATION AT SEA AND IN THE AIR.

By P. V. H. Weems, Lieutenant-Commander, United States Navy.

This article is the writer's opinion of what should comprise the equipment and methods for celestial navigation. Piloting, dead reckoning and compass work are omitted.

A complete list of the items of equipment for navigation follows:

1. Sextant, bubble type.
2. Two Chronometer watches, one set to Greenwich civil, and one to Greenwich sidereal time.
3. Nautical Almanac.
4. Charts, chart board, and either parallel rulers or a drafting machine. A drafting machine is handier.
5. Chosen method of working the line of position. The latest method is that given in the "Line of Position Book," which is meeting the approval of the navigators who have tried it.
6. Dividers, pencil, and work book.
7. Two-star altitude curves for use at night.

The writer has used a Bureau of Standards Navy bubble sextant for several months, during which time he has taken several hundred observations. Without a doubt this sextant would be a convenience to the navigator, and is a great improvement over the old style bubble sextant where a spirit level was attached to an ordinary sextant. In the old style sextant with bubble attachment, it was necessary to bring the body, the bubble, and the bubble marks together. This means that three objects must be viewed simultaneously, an operation which is about as easy as "rubbing the tummy and patting the head at the same time." With the Bureau of Standards sextant, it is only necessary to bring the observed body to the center of the bubble, when the latter is approximately at the center of the field. This operation can be done so easily that at first one is inclined to consider the method crude. As a matter of fact, results using this sextant are surprisingly close. Lincoln Ellsworth, on first trying out this sextant, made the observation, "It certainly looks crude to give such accurate results." This sizes up the matter perfectly. When used as a horizon sextant, this sextant is practically as accurate as a horizon sextant. When the bubble is used, there is an inaccuracy due to motion of the ship. Yet a sight with an error of ten miles is better than nothing. While an ordinary horizon sextant is an accurate instrument, a bubble sextant with horizon feature offers many advantages.

Another feature of the Bureau of Standards sextant which is especially good for night work is the fact that a star may be viewed direct through a plain glass, making it almost as easy to pick up a star as it is to see it with the naked eye. The bubble is lighted up by a small electric light controlled by a rheostat. When observing the sun, the bubble is viewed direct while the sun is reflected.

The sextant is handy to operate, light (2¼ pounds), compact, and easy to read. There is a small reading light for night work. Altogether, the Bureau of Standards sextant, while defective in minor details, is a highly satisfactory instrument and a great improvement over the old style sextant, with bubble attachment. Only six of these sextants were made, but an attempt is being made to induce the manufacturers, Bausch and Lomb Optical Company, to correct certain minor defects and to put the instrument on the commercial market. The cost should be about the same as a good horizon sextant and should prove popular with the navigator. There is a considerable advantage in being able to take an observation when the horizon is not visible.

The navigator needs two watches, one set to Greenwich apparent time for work with the sun, and one set to Greenwich sidereal time for work with the moon, stars, and planets. Thanks to the daily radio ticks, it is now a simple matter to check and rate watches. Since the correct time to the second can be obtained as often as needed, there is no longer the necessity

for keeping three chronometers carefully checked at every opportunity and compared daily. It might be desirable to have such instruments aboard ships at sea and out of radio range of time signals, but certainly they are not needed to give the correct time to navigators of small craft.

With the invention of the second setting watch, the exact second of time can now be kept continuously, and since the rate should certainly not vary more than two seconds per day, we might safely claim to have the correct time within a second, if we get the daily radio ticks and set the watch to the exact second of time. The second setting watch is a new invention, and gives a clear-cut saving of time and labor. The first of these watches was recently altered for the United States Navy by J. Jessops and Sons, of San Diego. The current Nautical Almanac (price 25 cents) is, of course, necessary item of the navigator's equipment.

There are numerous methods by which the line of position may be worked. The method we advocate as requiring one standard solution for all cases, and as the easiest and most compact, is that based on Ogura's altitude tables combined with Rust's Azimuth Diagram. With the kind permission of Ogura and Rust, the Naval Institute at Annapolis has published these two methods (one for finding altitude, and one for azimuth) in one book, the "Line of Position Book." Auxiliary tables made up for the convenience of the navigator are included, yet the book has only 44 pages and can be carried in the coat pocket. It requires no interpolation and is accurate under all conditions for which it is used.

TWO-STAR ALTITUDE CURVES.

In Technical Report No. 198, of the United States National Advisory Committee for Aeronautics, several methods for determining positions by observation of heavenly bodies were compared and discussed. Along with the other methods, K. Hilding Beij suggested the idea of using curves of simultaneous altitudes of two stars for obtaining the latitude and local sidereal time. The local sidereal time found is applied to the Greenwich sidereal time to get the longitude. The writer, who had been working on the idea of using the altitudes of two stars in tabular or graphic form for a simplified method of getting a fix, was impressed with this suggestion, and after further study, decided on this as the best of all the methods mentioned. It might be added here that Admiral Hugh Rodman's article, "The Sacred Calabash," in the August 1927 U. S. Naval Institute Proceedings, combined with the navigational problem involved in the Dole flight, induced an added interest in the general subject.

When the sun, moon, or planets are used for working the line of position, the right ascension and declination change so rapidly that special tables or graphical solutions for working the line are impractical. Any method offering a general solution to cover all conditions necessitates cumbersome and time-consuming precepts. Only when we pay the price of a restricted special case, can we arrive at short, simple, and accurate solutions. These restricted but simple methods, fortunately, may be applied to fixed stars, since their right ascension and declination remain over a period of several years so nearly stationary as to keep within the limits of accuracy required by aerial or small ship navigation, say within three miles.

Having once decided on the two-star altitude curves as the most promising method, such details as the scope, scale, and arrangement had to be worked out. A rather ambitious plan has been launched by which all latitudes from ten to eighty degrees north would be covered. The scale finally decided on was about one-fourth that of the Mercator projection plotting

sheets used at sea, or about 75 miles to the inch. Two general arrangements are possible—the curves may be made in one continuous sheet and kept on rolls, or it may be made up in sections and bound in book form. It is planned to produce the curves in both roll and book form, the former being somewhat handier for the air navigator or avigator, while the latter may be made more compact and at a smaller cost. It is convenient to have a roll or a book for each ten degrees of latitude, or some perhaps will prefer to have latitude twenty to fifty north in one volume, as this would include the United States except the extremely southern part.

These curves are made by plotting the altitude against latitude as the ordinate and with local sidereal time as the abscissa. H.O. 203 and H.O. 204 (Hydrographic Office tables) were used in computing the points on the curves.

In the construction of the curves, we interpolate for the star's exact declination, thereby avoiding the combination of latitude and declination of like and unlike signs required in methods of general application. Similarly, since a star has a nearly fixed right ascension (over a considerable period of time) we may combine the right ascension with the hour angle and use the resultant local sidereal time. This, in effect, eliminates from our problem both right ascension and local hour angle. Each curve of altitude is the loci of corresponding values of latitude and local sidereal time. If we choose a time we obtain a definite latitude, while if we choose a latitude on the curve, we obtain a definite time. An intersection of two altitude curves gives us a definite point, which determines at once a latitude for those altitudes, and a corresponding local sidereal time. Since the difference in time between the Greenwich and the local meridian is our longitude, to obtain a definite fix by means of the curves, it is only necessary to observe or compute the Greenwich sidereal time of the simultaneous observations, then with the intersection of the two altitude curves to read the latitude and the local sidereal time from the proper scales, and to take the difference between the two times for the longitude.

Theoretically, we must have simultaneous observations for two fixed stars. Practically, however, if we use Polaris for one of the pair, we need not take the time when the altitude of Polaris is observed, since its altitude varies so slowly as to be a negligible amount in ordinary sights. When necessary, the change of altitude due to change of position and the change of altitude due to interval of time between the observations of the two stars should be taken into consideration.

It will be noted that the simultaneous altitudes and time of observations of two stars definitely determine a fix *without reference to the dead reckoning position.* This last point is a most important one in navigation for the reason that one's dead reckoning position may be so much in error that plotting by the usual methods would be impracticable, even assuming that the computations could be made.

The Greenwich sidereal time of observation is required. The conversion of mean time into sidereal time is, alone, no small item. Fortunately, we may get around this difficulty by the common-sense procedure of keeping watch set to Greenwich sidereal time (GST). The GST may be kept to the exact second by having a movable second dial, so that seconds may be set.

Still another short-cut may be made in the construction of the curves: the bubble sextant correction, i.e., the parallax and refraction, may be included in the construction of the curves with the result that the sextant readings (if there is no index error) may be used to find the intersection on the curves. Thus by having a watch which will give us the exact GST,

and a sextant whose readings are used directly on the curves, the total computation for obtaining a fix is one subtraction of time for longitude. The latitude scale is plotted to the scale of the Mercator projection, and the point of intersection serves as a record of the latitude as well as of both altitudes. There is no need to write down the latitude, since it is shown to scale on a Mercator projection. Also, the longitude may be left in time units, and the work of conversion to arc thereby saved. The fact that there is so little writing to do is a big advantage.

Since only one subtraction is required, this may be written directly on the page near the point of intersection, and by numbering the longitude to correspond to the points of intersection a permanent record is kept of the work. The time of solution requires less than thirty seconds after the altitudes are observed. On test, the writer did the complete operations of taking two sights and obtaining a fix in 55 seconds. As it happened in this case, the latitude found was exact, and the longitude only one minute of arc in error. The average error on a steady platform should run less than four miles when a bubble sextant is used. The curves can do no more than give a correct solution for the altitudes and time used, and when the correct data are used, the solution by the curves should be correct within three miles at all times.

To enumerate the advantages of this method we have:

(*a*) *Speed.* Positions may easily be found in less than two minutes.

(*b*) *Simplicity.* There being no precepts to remember, and only one subtraction of time to make, anyone with ordinary intelligence may use the method.

(*c*) *Fool-proof.* Since there are few figures written down, and since all work is shown to scale, errors due to computations are avoided.

(*d*) *Handiness.* Since plotting is not needed, the equipment is reduced to a watch, a sextant, and a book of curves.

(*e*) *Tables and Nautical Almanac not needed.* Since only the altitude and GST are needed for getting a fix, the Nautical Almanac, log tables, and chart are not required.

(*f*) *Dead Reckoning Position not needed.*—"Pacific Marine Review," June, 1928.

OIL AND CORROSION.

By Horace J. Young, F. I. C.

A paper, entitled "Corrosion by Oil," was read recently by the author before the Institution of Petroleum Technologists.* It showed that samples of used lubricating oils drawn from the engines of motorships, automobiles, and other internal-combustion engines are found frequently to be corrosive to steel or white metal, or to both. It pointed out, also, that those tests ordinarily applied by chemists failed to detect this particular condition; this being true to the extent that certain oils which had caused immense damage were tested by chemists and reported to be innocuous.

The author's method of detection, called the D. O. C. (Direct Oil Corrosion) test, was *not* to analyze the oil but to run it over steel and white metal—in other words, "to try it." An apparatus, whereby this D. O. C. test could be carried out simply and easily, was devised, and the fact that it is in use today on several ships and in various laboratories speaks for itself.†

* "The Marine Engineer and Motorship Builder," November, 1927.

† See "Trade Publications" section of the May issue of this journal.

Those familiar with marine work know that the chief engineer has ever before him the specter of the condition of his oil. Corrosion on motorships is feared by everyone concerned. It has happened before, and it may happen at any time. It is a thing concerning which there has been no means of being forewarned. Therefore a simple apparatus whereby the chief engineer himself may keep a watch upon his oil, and see how it is behaving towards steel and white metal (also towards any other metal if he chooses to test it against some other), is not out of place. The application of this test would have saved large sums of money in cases where serious corrosion occurred before anyone suspected it. Indeed, even after the corrosion was discovered it was not known that the oil had caused it until that oil had been tested on the D. O. C. apparatus. 'A test having been found it became possible to work upon discovering a remedy. The result is a rectifier for insertion into the lubricating system of a motorship or automobile.

The attitude of the oil companies towards "Corrosion by Oil," has been instructive and appears to fall within three categories:—

Firstly, there are those companies who, having devoted both time and brains to the reading of the author's paper, have recognized that no better vindication of unused mineral lubricating oils could be published. The author plainly stated that he had found no such oil which was corrosive to steel or white metal; he stated also that very minute quantities of sulphuric acid or of acid sulphates made that oil corrosive in a similar manner to that of oils from internal-combustion engines. The author has met no engineer who has not known what this probably meant; he has known that the trouble probably *originated* in the combustion zone. In any case, some oil people have come to this conclusion, and have told the author that his paper relieves them from much of the anxiety and insinuation made by customers who get corrosion trouble and attempt to blame the lubricant.

The second category of oil companies comprises those who are trying to demonstrate that the cause is sea-water. That sea-water is important is true, but it does not happen to be the problem upon which the author was working; moreover, the fact that oils from automobiles show the same corrosive properties would appear to be evidence that sea-water is not the culprit. However, the more research done upon these matters the better for engineering.

The third class of oil companies is that one comprising those who have read the author's paper with insufficient care. This would not matter, provided discussion of the subject is carried out in public by both parties, so that everyone has equal opportunity of reading the discussion *and* the author's reply.

Recently, the author was shown a pamphlet issued by W. B. Dick & Co., Ltd. This pamphlet dealt almost exclusively with the author's paper. To his surprise, it consisted partly of an article published in "The Marine Engineer and Motorship Builder" of April, 1928,* plus the addition of many remarks which that article did not contain. The article was an ordinary scientific contribution under the name of the chemist to that company. The pamphlet is called a "Laboratory Report," but contains such phrases as "*We* may say"; "*We* feel certain"; "The customer will realize that his interests * * * are second only to *our own*," and so on.

The writer, being interested only in the science of the subject, approaches it solely from that point of view. That this elaborate pamphlet should have been thought worth publishing is a compliment. It remains to place before engineers the author's replies to certain remarks contained therein. The pamphlet states that the author "has implied that oil may become harmful

* "Corrosion in Internal-Combustion Engines," by John C. Jennings, Chief Chemist to W. B. Dick & Co., Ltd.

before it ceases to be effective as a lubricant, which, if correct, would be a very serious matter, not merely to oil users, but more especially to oil manufacturers." The answer is that the author stated as a fact that many used oils from motorships and automobiles had been found to be corrosive. The pamphlet proceeds to give the results of tests on new oils which results confirm those published by the author, namely, that unused mineral oils are not corrosive. The pamphlet then describes how contamination of the unused oils caused them to become corrosive. This, again, is precisely what the author's paper said. The pamphlet states that the author's tests "will lead to erroneous results if carried out without attention to certain precautions." Such a remark applies equally to any test of any kind. All the original tests were conducted against blanks, and in no case was any erroneous result obtained. No better proof of this can be offered than the fact that the elaborate tests described in the pamphlet confirm the simpler ones done by the author.

Dealing with the D. O. C. test, the pamphlet remarks: "It is also obvious that no reliance can be placed upon direct corrosion tests unless the complete history is known of the samples tested." Why the direct corrosion test is particularly affected in this manner is left to the imagination. It is fallacious to suppose that the Dick laboratory has a test upon which reliance can be placed when the complete history of the sample tested is unknown. Speaking of the author's results, the pamphlet says: "It is a logical inference, and one which is at least worthy of investigation, that all the author's used oils had been subject to outside contamination during use in the engines, but that the author apparently did not think it of sufficient importance to investigate this point or to mention it." The whole of the author's work was directed towards explaining corrosion which occurred in practice and, as the pamphlet truly says, the logical inference is that the lubricating oils had been subject to outside contamination.

Somewhat humorously, the pamphlet states that "It would be unflattering to the 'practical engineer' to suggest that he will be 'satisfied' with the work as carried out by Mr. Young." It omits to explain "why?" The author carried out his work to the best of his ability; everything he did has now been confirmed by the further work given in the pamphlet; and the practical engineer appears to be satisfied that his oils *are* liable to become corrosive in the manner suggested by the author. Perhaps the real complaint of this pamphlet is voiced in the following extract. "It is obviously unfair to the lubricating oil companies to broadcast a paper with a title which has had the effect of leading consumers to draw conclusions which are not supported by the evidence of his investigations." The title of the author's paper was "Corrosion by Oil," *not* "Corrosion by Lubricating Oil." It would appear to be a perfectly fair title. Certain used oils had been reported by chemists as perfect. By the author's D. O. C. test they were found to be corrosive to both steel and white metal. The probability that lubricating oil is contaminated by products of combustion of fuel oil seems to further justify the title. Moreover, the paper was read before a scientific society, and was open to all members for public discussion.

Returning to the humor of the pamphlet, the following is worthy of attention. It says: "We feel certain that the work carried out and recorded will prove to the satisfaction of the engineer that no oil which has been approved by these laboratories can, by any possibility, cause pitting or corrosion on any part of his engine. Should this unfortunate circumstance arise. * * *" Of course, what the pamphlet probably intends to say is that their mineral oils, by reason of the care taken in choosing them, will not deteriorate so as to cause pitting or corrosion. The author is willing to suggest that this is correct, and that no word of his paper stated otherwise.

The pamphlet is spoiled, as a "Laboratory Report," by remarks of the following order: "Oil suppliers of repute who have at their disposal a technical engineering staff can mutually assist the designers and users of Diesel and other types of internal-combustion engines." So far, so good; but the paragraph goes on to say: "The result of such active cooperation will be *an entire absence from such trouble as corrosion.*" However, the activity of this spirit of cooperation does not extend to the author's D. O. C. test because the pamphlet says: "We may say in conclusion that we consider an apparatus for detecting corrosion such as that described, or any modification of it, is entirely unnecessary." Yet the facts are as follows: The apparatus solved two important cases of corrosion. Chemists' tests had failed to solve them. The pamphlet describes no alternative test. The author himself knows of no alternative test, and would choose always the "direct" test as ideal for detecting corrosive properties of oil.

Apart from the corrosion of bearings there are innumerable problems which may be related to corrosion by oil and which require close attention. Deterioration of cylinders, cylinder liners, piston rings, inter-cooler tubes, tanks, pipe-lines and so forth, come to mind as belonging to this subject. What we know about the ultimate affects of oils and of oil-burning upon engineering structures is very little. Everyone believes that the oil companies are doing their best to supply reliable materials. There is not one suggestion in the author's paper to the contrary. What he attempted to do was to throw some new light upon the corrosion problem and to demonstrate that the tests of chemists—he is one himself—are not always what they seem. A little investigation into any method of physical or chemical testing reveals frequently that it is subject to limitations of which we were unaware. Research upon oil problems should not be left entirely to the oil companies. Users should conduct independent work in the interests of both parties.

The pamphlet was written apparently in order that no engineer should be misled about lubricating oil by the author's paper. The author, on the other hand, has written this reply in order that no engineer shall be misled about the author's paper by the pamphlet. If anyone is sufficiently unwise as to believe that good mineral lubricating oil deteriorates so as to become corrosive in the degree demonstrated by the author's paper he may know now that it does not. The views of W. B. Dick & Co., Ltd., and of the author, are similar, although expressed differently. Cooperation is good—and possible.—"The Marine Engineer and Motorship Builder," June, 1928.

PROBLEMS OF DIESEL ENGINE SELECTION.

Once a shipowner and his engineering advisers have banished the idea of steam power for a new ship, the matter of engine selection may not seem to be an easy one, because there is a large variety of Diesel types from which the selection must be made. On all sides the prospective motorship owner is bombarded by the claims of the oil-engine salesmen extolling the merits of 2-cycle, 4-cycle, single-acting, double-acting, opposed-piston, airless-injection, air-injection, high-piston speed, low-piston speed, gear-drive, electric-drive, trunk-piston, cross-head design, etc., all of which types are in service at sea giving excellent reliability.

In the last few words the shipowner may find in the final reckoning one answer to his problem. For any well-designed Diesel engine built and put on the market by an engineering company of repute and experience will be found to be a good engine. In other words, if the owner goes to any responsible oil-engine organization in this country whose reputation is established he is going to get an engine that will stand up to the work of pro-

pelling his ship, even in a more reliable manner than the marine steam-engine and boiler plant to which he has been accustomed for years.

"Even so," remarks the owner, "just how shall I make the selection from the 57 varieties offered me? The 'Motorship Manual,' for instance, classes Diesel marine engines as follows, and to this classification I have added the V-type four-cycle engine:

"Here are outlined enough different designs almost to bewilder me as an owner without first-hand experience of any of these types. Just what shall be my guiding factor?"

The ship herself and the service in which she will be engaged are the pivotal points on which to base the selection. Wrapped up in the ship and her work, and embodied in her design, are the engine-room, its machinery, and the cost of the entire job.

Consequently, the simplest plan for engine selection is to enumerate the main points, namely:

1. Class of Vessel and Service.
2. Voyage length and Net-Cargo Capacity.
3. Twin or Single Screw.
4. Propeller speed and engine speed.
5. Maximum desirable machinery length.
6. Maximum desirable machinery height and width.
7. Maximum desirable machinery weight.
8. Good Sound Engineering.
9. Engine Balance.
10. Accessibility and Maneuverability.
11. Fuel consumption.
12. Maximum Cost Economically Permissible.

Reliability and durability should be eliminated from this particular comparison, because we already have accepted the premise that only reputable, well-known engines are being discussed, the reliability and durability of which have been established over periods of operation in marine and land service. Freak designs and experimental types are not being discussed.

"Just where shall the line be drawn between trunk-piston and cross-head types and between single-acting and double-acting types?" The answer to the first mentioned is largely answered in the limitation of factors Nos. 1, 5, 7 and 12. The art of Diesel construction has made such rapid progress during the last few years that for certain types of vessels trunk-piston construction is very satisfactory, and preferable, up to about 3000 brake horsepower per engine, and possibly over within certain revolution limitations. Where headroom, light weight and low first cost are the main considerations, fuel and lubricating oil consumptions are secondary—provided they do not vary too greatly. With a big, slow-speed engine, cross-heads are, of course, highly desirable and advisable. But good, sound engineering always is very essential.

The problem of selecting single-acting or double-acting engines may be solved if the owner bases his decision on points, at least where engines up to 5000 shaft horsepower are involved, as follows:

	Points
Good Engineering	25
Overall length	20
Weight	20
First Cost	15
Accessibility	10
Height	5
Fuel and Oil Consumption	5
Total	100

Classes of Marine Oil Engines

4-CYCLE	SINGLE-ACTING	*Trunk piston*	*Air injection*	*Diesel*
			Airless injection	*Diesel*
				Hot surface ignition
		Crosshead	*Air injection*	*Diesel*
			Airless injection	*Diesel*
				Hot surface ignition
	DOUBLE-ACTING V-CYL. ARRANGEMENT	*Crosshead*	*Air injection*	*Diesel*
			Airless injection	*Diesel*
		Trunk piston	*Airless injection*	*Diesel*
2-CYCLE		*Trunk piston*	*Air injection*	*Diesel*
			Airless injection	*Diesel*
				Hot surface ignition
		Crosshead	*Air injection*	*Diesel*
			Airless injection	*Diesel*
				Hot surface ignition
	DOUBLE-ACTING	*Crosshead* / *Sliding cylinder*	*Air injection*	*Diesel*
	OPPOSED PISTON	*One crank per cylinder*	*Air injection*	*Diesel*
		Three cranks per cylinder	*Airless injection*	*Surface ignition*

These points should be modified with varying type of vessels and for special service.

Vibration also need not be included, as vibration being so dependent on the design and construction of the ship, her engine foundations, the auxiliaries, and the amount of power for a given hull construction, that it is a matter more for the naval architect than for the engine builder, because the modern Diesel engine is well-balanced as a power unit before it leaves the shop. With a two-cycle engine good balance can always be secured from four cylinders, and from six cylinders with the four-cycle type. More cylinders are optional.

In between the single and double-acting designs comes the opposed piston engine, the performance of which in service has fully justified its existence and present position in the marine world. So far its construction has mainly been restricted to big cross-head engines of 70 to 130 R.P.M., although a few higher speed engines have been placed in service showing that the design is not limited to slow speed. The same points, one to twelve, can well apply when making a comparison with other types. This also is largely the case when arriving at a decision over direct, electric or gear drives. Considerations and personal prejudice as a rule are in actual practice the decisive factors in making a choice of engine—not a wise policy.

It would be idle to say that all motorships without exceptions have been completely successful, but in nearly every comparatively rare case of serious trouble or failure, the difficulties encountered could be traced to rash claims for an untried design, to poor operation, or to a short-sighted policy of the owner, or his "expert" adviser, who insisted on buying a marine oil-engine power-plant solely upon a price basis. When first cost is the prime consideration with a shipowner he generally winds up by forcing the price level below the point at which a good Diesel engine can be built commercially. Or, he is beguiled into underpowering his ship. He throws away months of expert studying and weighing of engineering fundamentals and pays more in the end. An engineering study of Diesel designs is time and money wasted, if price be the determining factor.—"Motorship," July, 1928.

PRE-HEATED AIR FOR BOILER FURNACES.

In the search for higher efficiency with marine steam engine plants a considerable amount of attention is being paid to the steam generators and their auxiliaries. The demand for higher initial steam pressures at the engine stop valve has a fundamental effect upon the design of the boiler itself since, by general agreement, the ordinary cylindrical return-tube type of boiler is not suitable for generating steam at a pressure of, say, 500 pounds per square inch and upwards, and if such pressures are demanded then it is almost a *sine qua non* that some form of water-tube boiler must be employed. Again, since steam at high pressure has a high saturation temperature, it follows that the temperature of the products of combustion leaving the water-tube boiler must be higher than those leaving the Scotch boiler generating steam at a lower pressure, and hence, if a high boiler efficiency is to be maintained steps must be taken to utilize a portion of this heat before it passes into the atmosphere. It is for this reason that with modern high-pressure steam installations air pre-heaters are employed, the purpose being to utilize the heat of the flue gases, which would otherwise be wasted.

The idea of utilizing the heat of the flue gases to raise the temperature of the air of combustion before it is delivered to the furnaces is, of course, far from being of recent introduction, as it has been employed in the Howden

system of heated forced draught in conjunction with the ordinary cylindrical marine boiler. This system, however, must not be confused with what is usually termed the use of pre-heated air, as with the Howden heated forced draught the temperatures involved are very much lower both as regards the flue gases and the air delivered to the furnaces. With modern air pre-heating installations, the temperature of the air leaving the pre-heater is of the order of 500 degrees F., depending upon the boiler pressure, whereas, in the arrangement as usually adopted on cylindrical marine boilers, the air temperature seldom exceeds about 250 degrees F. As indicating the higher air temperature which the newer forms of pre-heater yield, it may be recalled that at the trials of one of the Yarrow water-tube boilers of the Canadian Pacific cargo steamer *Beaverburn*, the temperature of the air entering the combustion chamber was 323 degrees F., although the boiler pressure was only 226 pounds per square inch.

As a result of this higher air temperature not only is there a greater increase in boiler efficiency consequent upon the greater absorption of heat by the air used for combustion, but the conditions under which combustion actually occurs in the furnace are also different. In a paper entitled "Pre-heated Air for Boiler Furnaces" presented at the recent meetings of the Institute of Fuel, the author, Mr. P. H. N. Ulander, calls attention to the difference in the furnace conditions consequent upon the use of highly pre-heated air as compared with those which obtain when low temperature or cold air is admitted to the furnace. The value of the pre-heater lies, therefore, not merely in the recovery of heat which would otherwise be wasted and the consequent reduction in the flue gas loss, but in the improved thermal conditions of the combustion process due to the higher initial and final temperature at which combustion occurs. Owing to this higher temperature the proportion of heat which is transferred by direct radiation to the heating surface of the boiler is increased, and since heating surface exposed to radiation is of greater importance than that exposed to convection the steaming capacity of the boiler is increased. Indeed, Mr. Ulander goes so far as to suggest that the use of pre-heated air, with its consequent increase in the amount of radiant heat in the furnace, demands an improved design of boiler, in which as large a portion as possible of the heating surface is exposed to the effects of this radiant heat. This improvement in the design of boilers is already to be found in land installations, where the usual refractory walls are replaced by water screens, and it has been shown that these are responsible for the absorption of as much as 20 per cent of the heat of combustion. The use of large furnace boilers with water screens such as are used on land is obviously impracticable on board ship, but it will be noticed that boilers such as those of the Yarrow type do tend to approximate to the water-screen type used on land in that the furnace is bounded everywhere except at the front and back with useful heating surface, which can absorb to the utmost the radiant heat in the furnace.

Many other effects following the use of highly pre-heated air could be noted, but it will be sufficient to mention that in addition to the higher efficiency and the increased rating of the boiler, the efficiency curve is found to be flatter than for boilers working with cold air. This means that over a wide variation of load or steaming capacity the boiler is working at approximately maximum efficiency, a feature which is of considerable value, particularly on vessels which have to steam at varying speeds. As against the many advantages which are obtained when highly pre-heated air is employed in marine boilers must be set the additional cost and weight of the installation and the increased wear and tear due to the fact that the furnace of the boiler is working at a higher average temperature, but if careful attention is paid to every detail of the design, this last should not prove a difficult matter to overcome.—"Shipbuilding and Shipping Record," April 26, 1928.

STANDARDIZATION OF WELDING.

Although there have been, and will be, many discussions regarding standardization in various branches of engineering, it is perhaps a little surprising that so little has been said as regards standardization in the welding industry. Having regard, however, to the admittedly difficult questions which arise in welding, whatever the process adopted, it is by no means an easy matter to know where to start. Notwithstanding this, the paper read before the Institution of Welding Engineers on May 15 is to be welcomed as practically the first attempt in this direction, and it certainly opens up new ideas and serves to emphasize perhaps more clearly than hitherto has been suspected, the real complication of the whole subject. There are, for instance, different issues to be faced as between new work in which welding is employed and repair work, and although on the surface the suggestion of standardization carries a good deal of conviction with it, it becomes clear, the more the matter is probed, that anything like complete standardization is out of the question, and that as a start, at any rate, only details can be dealt with from this point of view. In the meantime, of course, there has been a great deal of standardization of welding apparatus on the part of manufacturers. For instance, one particular firm has put out an extremely useful range of oxyacetylene welding apparatus for small and large work, which has proved of immense value to users, and the whole of that is of such a standardized nature that the particular items can be replaced at a moment's notice and continuity of work maintained. The same may be said of the various electric welding processes, but when one speaks of standardization of welding a rather more comprehensive meaning is involved, and deals more with the work than the apparatus.

The writer of the paper in question, Mr. P. L. Roberts, indicated in a very clear manner what he is aiming at, and, as a matter of fact, he included some points relating to apparatus as well as to the work. It seems almost inevitable that we should be referred to America for information of what can be done, and it is only common fairness to record that the American Welding Society has already prepared standards of one form and another covering many sections of the welding industry, although even there it will not be claimed that they are complete. Yet they clear the ground for more comprehensive standards as experience is gained. Among the details pointed out in the paper are the use of the most suitable joint for the particular purpose—the conditions in which a particular type of joint should be used being indicated—methods of preparation, the amount of welding material to be used, the finish of the weld, and so on.

It seems obvious to suggest, inasmuch as the matter has received this prominence before the Institution of Welding Engineers, that that organization should appoint a committee to go into the whole matter, and Mr. Roberts, the author of the paper, may safely anticipate that for his sins in bringing the matter forward he will at least be a member of that committee, if not taking a more prominent position. There are so many details to be thought out that it would be impossible to deal adequately with them at a meeting of the Institution itself. It is essentially committee work, and when the ground has been thoroughly prepared, then it might well be handed over to the B. E. S. A. for final consideration, because by that time ideas would have crystallized themselves sufficiently for really practical work to be done and some standards formulated. That there are difficulties in the way will not be denied, but at the same time it does not require very deep thinking to appreciate that there is quite a lot in a tentative way that can be done now without in any way stultifying technical progress, which is so much feared when

standardization is spoken of nowadays. That there is a real danger of that cannot be denied, for we have one or two striking examples of it before us, in other directions, at the present time.

It is astonishing that so little attention should have been devoted to the glasses which operators have been working with, and attention seems only now, for the first time, to be drawn to the fact that quality of these glasses seriously affects the quality of the work. In this country we have been content largely to use ordinary glass just smoked, irrespective of the nature of the eyesight of the particular operator. As a matter of fact, it is alleged that it is impossible to get really good glass for goggles in this country, although we are quite prepared to hear from English makers that this is not so; yet the fact remains that one speaker in the discussion on the paper in question stated that he had purchased glass for this purpose from every glass-maker in this country, but had not found any of it come up to that which he obtained from America. Certainly the provision of suitable glasses for the operators is an outstanding necessity, and in itself affords quite a deal of work to settle. From other sources we learn that at least two firms in this country are able to supply suitable glass for welders' goggles.

INDUSTRIAL DISPUTES.

The fact to which attention has been drawn from time to time in these notes of the development of a really harmonious spirit between workers and employers, following the disastrous events of 1926, is amply confirmed by the Ministry of Labor statistics for 1927, during which year it is shown there was less time lost in consequence of disputes than in any previous year during the period in which these statistics have been collected. It may surprise some people to know that, notwithstanding this fact, there were in 1927 no fewer than 308 labor disputes, but it can at once be said that they were of small moment. Yet there were 1,174,000 working days lost, and these are figures which indicate with emphasis how damaging to the prosperity of the country are even the small disputes. It cannot be too much impressed how big disputes affect the welfare of the nation. In 1926 the working time lost amounted to 162,233,000 working days, a deadweight which we shall never recover in terms of cash. In the same way the statistics show that the next highest figures of hours lost were in the year 1921—another coal-mining-dispute year—when the working days lost amounted to 85,870,000. It can only be hoped that the example set by 1927 will be improved upon, and that there will not be a tendency to revert to the old bickerings the moment there is the slightest indication of a particular industry showing a little prosperity. It is up to both sides to achieve this, and all the signs are in that direction.

THE INSTITUTION OF ELECTRICAL ENGINEERS.

The annual general meeting of the Institution of Electrical Engineers and the issue of the council's report serve as a reminder of the rapid growth of the electrical industry. The membership now exceeds 13,000, although some people may think that even that is relatively small compared with the number of people engaged in the industry. It must be remembered, however, that the Institution stands for a high standard of qualification, and that only really trained electrical men can enter. There are heaps of others who trade electrically in some form, but they fall very far below what would be required for membership of the Institution. As a matter of fact, there has been a prosecution during the year against a person for using an indication of membership in an unauthorized manner, and although such cases very rarely arise, it is hoped that the result of this particular action, in which

the person in question had to pay costs and undertake never to adopt the same practice again, will be a deterrent to others. Another matter of some interest is the readmission to membership of those who were expelled during the war as being enemy members. One would rather imagine there is some difference of opinion on the council as regards admitting to membership nationals of countries at one time at war with us, judging from the guarded manner in which the president replied to some questions on the point—questions, by the way, which have been put at the two previous annual meetings and have met with the same response, that the council has the matter under consideration. A rather surprising feature of the membership is the fact that during the past year, although 700 new student members were enrolled, several hundred ceased their membership. On the face of it, this calls for some explanation, and one which has been put forward in a somewhat facetious manner is that, in the enthusiasm of youth, the attractions of the electrical industry draw the young students into the Institution, but that when they have had a little time to probe into matters and find what poor men electrical engineers are, they promptly seek pastures new and go into other branches of engineering. That may be part of the truth, but anyhow it is a matter which is enagaging the close consideration of the council. In the meantime, things are going very well for the I. E. E., and everybody welcomes back to health again the popular secretary, Mr. Rowell, who has been through a very bad time during the past few months.

SHEFFIELD AND THE MERCHANDISE MARKS ACT.

There has been going on during the past few weeks an inquiry, under the Merchandise Marks Act, relating to an application of the Sheffield Cutlery Manufacturers' Association that all imported cutlery should be marked in some distinguishable manner to indicate that it is of foreign origin. The inquiry is now completed, and the Standing Committee will report in due course. This inquiry affords yet another example of the extreme difficulty of dealing with the fiscal aspect of the iron and steel industry and that everlasting problem of what are British goods. One of the largest manufacturers of safety-razor blades in this country, away from Sheffield, openly admits that he purchases the blanks for his blades from Sweden, his reason being that he cannot get what he wants at his price in this country. Hence he objects to the marking of imported safety-razor blanks because at present his finished blade goes out as manufactured in this country. On the other hand, it is alleged that a large proportion of the blanks used in this country for making scissors and knife blades are imported and finished into products which are ostensibly sold as British. The same thing is going on all over the place. We know the shipbuilding and other industries adopt the same policy. It is perhaps not surprising that the Government hesitates.—"Mechanical World," June 1, 1928.

TRAINING, INSPECTION AND SUPERVISION.

Discussed at Welding Session.

A news report in last week's "Power" outlined the proceedings of the annual spring meeting of the American Welding Society, held in New York, April 25-27. Aside from the meeting of the committee on pressure vessels perhaps the most significant session from the point of view of the "Power" reader was that devoted to a preliminary progress report and discussion on the qualification of welders, inspection and supervision.

The report was presented by H. H. Moss, of the Union Carbide & Carbon Company, and discussed by A. M. Candy, of the Westinghouse Electric & Manufacturing Company; C. E. Loos, American Bridge Company; G. A. Caldwell, Mississippi Valley Structural Steel Company; E. E. Shanor, Petroleum Iron Works Company; W. C. Beakley, Whitlock Coil Pipe Company; N. E. Wagner, Prairie Pipe Line Company; A. O. Miller, Reeves Brothers; L. H. Burkhart, Struthers Wells Company, and S. W. Miller of the Union Carbide & Carbon research laboratories.

Standards, Mr. Moss stated, must be kept within the ability of the average workman; undue complication must be avoided. Design for welding is the first thing to consider. Stress transfer at the joint must be properly allowed for. The next step, he said, is to make sure that the job is properly prepared and set up and the proper welding rod employed.

The following is an outline of the remainder of Mr. Moss' report: For butt welding of materials thicker than three-sixteenths inch the edges must be beveled to get proper penetration. The dimensions of fillet welds are determined by the strength in the throat, which is the critical point.

Material for welding should be carefully selected. Common defects in the steel are dirt, slag, laminations and segregated carbon. These are easily detected by melting the edge of the metal.

Supervision is a matter of the first importance. The supervisor must make sure that the welder understands his directions and follows them. He should see that the work is carefully prepared and well set up. In piping work flexible templets should be provided if possible.

The function of inspection is to enforce the standards laid down. More and more it is becoming the practice to depend on disinterested commercial laboratories for the necessary tests. Inspectors of building departments and insurance companies will also have an increasing share in this work.

Rigorous tests for the qualification of welders will eventually help the welders themselves as well as the welding industry. When a test is first imposed on a welder, it is a training episode. Later tests tend to refine and perfect his work. Insistence upon proper qualification helps the employer by insuring good work and few comebacks.

In pipe work two standards of qualification are recommended, one for men limited to work on straight lines and the other for the higher-class welder to whom can be entrusted all jobs relating to power-plant piping, tanks, etc. The cost of qualifying the men may be an appreciable item, but it is more than balanced by other factors.

Sometimes tacking is done by one man and the weld completed by another. In such cases each welder should have separate instructions.

As to the physical properties of welds, the test strength required must depend on the character of the work, but in practically all cases it is fair to require that the weld be as strong as the base metal.

Commenting on the paper of Mr. Moss, F. T. Llewellyn, president-elect, who presided at the meeting, said that qualification of the designer was an even more pressing need today than qualifying the welder. It is one thing to know how to make an individual weld and quite another to know how to combine welds properly in an actual structure. Mr. Llewellyn said that confusion would be avoided if standards for gas and electric welding could be kept as much alike as possible.

The welding supervisor, said C. E. Loos in a prepared discussion, should have all the abilities of a shop superintendent in knowing who can best do each job. He suggested that each workman be required to indentify his work by stamping his personal mark upon it. This would tend to eliminate failures due to qualified but careless welders. One of the best tests for a

welder, said Mr. Loos, is to require him to joint two pieces of different thicknesses. The weld should then be broken to study its quality.

Character is an essential qualification of any welder, declared G. A. Caldwell. The man must have a sense of responsibility. The welder should be a man who wants to weld. Here, said Mr. Caldwell, is a new skilled trade to take the place of some of the vanished trades of the past.

Speaking of training and procedure for welding large-diameter steel pipe, E. E. Shanor said that electrically welded pipe is being used more and more for hydraulic installations and water supply as well as for gas lines. The procedure in his shop, he said, is to deposit one layer of weld metal, then peen and inspect before applying the next layer. No welds made in this way have failed.

W. C. Beakley said that his company uses gas, electric and resistance welding. To qualify welders a test coupon is bent in the vise and a butt weld sent to the testing laboratory. Supervision is closely controlled. Welders are required to fuse out all tack welds.

A welded rotary lime kiln 100 feet long was described by A. O. Miller. This has operated for four years without trouble. He showed slides of large welded pressure vessels made over a period of years. The latest designs displayed had elliptical heads with slab manholes welded in. His experience, Mr. Miller declared, gave him absolute faith in the future of welded pressure vessels.

The double-Vee weld was recommended for all work by L. H. Burkhart. He pointed out that the double-Vee requires only half as much weld metal.

S. W. Miller, in concluding the discussion, stressed the importance of procedure control. He said it was a cause for congratulation that welded pressure vessels, once strongly opposed, have now gained a preferred position.—"Power," May 8, 1928.

THE NAVY AND SCIENTIFIC RESEARCH AND EXPERIMENT.

It was a frequently heard criticism during the years immediately preceding the war, that in our numerous industrial activities, scientific research and experiment were almost wholly neglected, and, as a consequence, the methods and processes employed in our workshops and factories were old-fashioned and costly. Since the war, such complaints have been less frequent, and, in fact, have to a large extent ceased. This is fully explained by the action of the Government in accepting the suggestions of the critics and adopting research as one of the principal duties of all State Departments. It would seem as if it were only the grim necessities of the war which forced the Government, in July, 1915, to pass an Order in Council which eventually resulted in the establishment of the Department of Scientific and Industrial Research. This Department has been continued, and staffs for scientific research have been added to nearly all the State Departments, the nature and direction of the work undertaken being determined by the needs of each Department. The Department of Scientific and Industrial Research is kept in touch with the work of the staffs in the various Departments, with the object of securing co-ordination and of preventing any duplication or overlapping. A glance through the details of the estimates of the various Government Departments recently presented to Parliament, will give some idea of the cost and of the numbers of persons who are to be engaged on research during the present financial year, and, in many instances, the general nature of the work, whilst the growth of research in the Departments, can be obtained by a comparison of such figures with those

appearing in the estimates for a pre-war year. A complete comparison for the whole of the Government Departments would prove a task of some magnitude, but, as an indication of the general tendency, the following details taken from the Navy Estimates of 1928 and 1914-15, are of interest. It may be remarked that the Research Department of the Admiralty has been developed from the Board of Invention and Research which was established at Victory House under the presidency of the late Lord Fisher, in July, 1915, at the same time as the initial steps were taken for the formation of the Department of Scientific and Industrial Research. The Board continued its work throughout the war, but was closed down soon after the Armistice.

Vote 6 of the Navy Estimates is for scientific services, and is the section on which the major portion of the cost for scientific research falls, but other sums for the same purpose are included in other Votes, and will be noticed in their place. The gross estimated cost of scientific services for 1928 is 503,894£, as compared with 99,648£, quoted in 1914-15. Both sums are subject to certain deductions which reduce the net costs of Vote 6 to 432,500£, and 64,700£ for the two years, respectively. In the two sums deducted the amount realized by the sale of charts is the largest item, being 56,000£ for 1928 and 32,500£ for 1914-15. The numbers of persons provided for in Vote 6 are 1207 in 1928 and 128 in the earlier year.

Subheads A to L of Vote 6 appear in the Estimates for both years, and include the costs of the Royal Observatory at Greenwich, the observatory at the Cape of Good Hope, the photographic mapping of the heavens, the Hydrographic Department of the Admiralty, the naval museum at Greenwich, the preparation and publication of the Nautical Almanac, and the purchase and repair of chronometers for the Navy. These various services employ 274 persons as compared with 128 in 1914, the estimated costs being 120,694£ and 98,943£, respectively. The largest subhead is E—Hydrographic Department—which employs 184 persons at a cost of 67,755£, compared with 80 and 21,362£ in 1914, but in the present year a staff of 70, costing 16,000£, appears for the Admiralty chart establishment at Cricklewood, for which there is no similar entry in 1914.

Subhead LL of Vote 6, Compass Department, includes 93 persons costing 23,235£, to which the Air Ministry contributes 7,500£, for research work on air compasses. In the 1914 Estimates, the Compass Department was included in Vote 12, Admiralty Office, and numbered four persons, costing 1753£. Subhead M is for Admiralty contributions to scientific institutions, and amounts to 2335£, of which 1360£ is to the funds of the International Hydrographic Bureau. In 1914 the sum under this subhead was 705£.

The remaining subheads of Vote 6 are set out in the following table, there being no corresponding figures in the Vote for 1914-15:—

The only establishment in this table which appeared in the 1914-15 Estimates is the Haslar experiment works, then included in Vote 12 as a part of the Constructor's Department, and numbered 16 persons, costing 2823£. A note in the current Estimates states that this establishment is engaged on experiments and investigations on the resistance and propulsion of ships and similar problems.

Of the 169 persons of the research staff in the first line of the table, 76 are described as scientific, and the remainder as technical. They form a pool from which the staffs for the various establishments are drawn, and it would appear from the figures given for 1927 that 24 were engaged in the Mine Design Department, 37 in the Signal School, and 10 in the anti-submarine establishment at Portland, increasing the numbers under subhead P by these figures. The allocation of the remaining 98 is not stated.

Notes accompanying the Estimates state that the Laboratory at Teddington is engaged on researches, which in their initial stages do not require a sea environment. When a sufficiently advanced stage has been reached, the research is continued in a suitable establishment—Signal School or Mine Design Department—research and development then proceeding together, the necessary members of the scientific and technical staff being loaned to the selected establishment.

Subhead.	Description.	Number of Persons.	Estimated Cost.
N.	Scientific and technical staffs for research in naval establishments	169	£ 86,925
	Scientific Research and Experiment Department at the Admiralty	8	2,132
	Admiralty Research Laboratory, Teddington	75	14,941
	Admiralty Engineering Laboratory, West Drayton—		
	Engineering section	57	14,385
	Electrical section	27	6,709
	Haslar Experiment Works	16	4,728
	Chemical research and experiment	58	16,131
	Holton Heath R.N. Cordite Factory, chemists and assistants	8	4,187
	Total Subhead N.	418	150,138
NN.	Analytical chemists	46	16,716
O.	Grants for maintenance of research establishments and laboratories	—	126,752
P.	Mine Design Department, Portsmouth	150	27,145
	Signal School, Portsmouth	179	29,883
	Anti-Submarine Establishment, Portland	47	6,996
	Grand total	840	357,630

The Engineering Laboratory at West Drayton is engaged on researches and experiments with heavy fast-running marine oil engines, metallurgical and engineering problems in connection therewith, and experiments in the initial stages of naval-engineering appliances. The electrical section deals with electrical problems, and, in part, carries out research and experimental work relating to electrical machinery for naval purposes.

The 58 persons engaged on Chemical Research and Experiment are employed at Porton Experimental Station, principally on work appertaining to Chemical Warfare, the War Office being jointly interested in the station, and being represented by its own staff of experts.

Of the 46 analytical chemists appearing in Subhead NN, 21 are at Portsmouth Dockyard, 10 at Sheffield, 2 at Greenock, and 13 at Holton Heath Cordite Factory. In the 1914 Estimates, the only similar entry is for the Admiralty Chemists' Department at Portsmouth Dockyard, the staff numbering 9, and the cost 4366£, as compared with 7600£ for 1928.

The largest individual item in Subhead O, of Vote 6 is 70,764£, for Chemical Research and Experiment, an Admiralty contribution to the War Office, etc. Other sums are 18,500£ for the Engineering Section of the West Drayton Laboratory, making a total with the sum in Subhead N of 33,000£; 6000£ for the Electrical Section at the same place, making 12,700£ in all; 22,000£ for other laboratories, including Teddington, and the Haslar Experiment Works; and 5700£ for Searchlight Carbons Research, and contribution to the War Office for Aerial Acoustic Research.

Notes in the Estimates outline the functions of the three establishments appearing in Subhead P. The Mine Design Department is under H.M.S. *Vernon*, and is engaged on the development of designs of mining and anti-mining weapons and devices, under the direction of naval officers. The cost of the latter is included in Vote 1, and the number so engaged is not given, but the Navy List mentions about 80 officers borne on the *Vernon* for torpedo and other duties, presumably including mining. The estimated cost of mines and anti-mining devices to be ordered in 1928 is not given, but Vote 9 includes 44,866£ for torpedoes, mines, paravanes, depth charges, torpedo and electrical stores, and explosives and stores required for torpedo and mining schools.

The Signal School is an establishment for experiment and instruction in wireless telegraphy and other methods of fleet communication. The latest scientific discoveries which appear useful for such purposes are closely investigated at the school, and developed into practical form if found suitable. Instruction, experiment, and development thus proceed together. In addition to the 37 members of the research staff, and the 179 civilians in Subhead P, 35 naval officers are on duty at the school, 12 of these being borne for experimental work. The pay and allowances of the naval officers are included in Vote 1. In the 1914 Estimates, the only persons stated to be engaged on wireless telegraphy were three civilians, their salaries of 1400£ falling on Vote 4. This increase in numbers from 3 in 1914 to 250 in 1928, indicates the enhanced importance of wireless telegraphy in naval operations.

Another note states that the Anti-Submarine Establishment at Portland has been reorganized and is equipped with a scientific staff and laboratories for the development of anti-submarine material, and is engaged in the dual functions of training and experiment. In addition to the civilian staff of 57, 27 naval officers are attached to the establishment. No corresponding provision appears in the 1914 estimates.

Vote 6 does not completely cover the cost of research and experiment, substantial amounts appearing in other votes. In Vote 8, the following sums for experimental purposes are mentioned, viz., 3000£ for propelling machinery; 1000£ for auxiliary machinery; 700£ for the hulls of warships, 25,000£ for armor; and 49,000£ for gun-mounting and air-compressing machinery, a total of about 79,000£. The only corresponding figure in the 1914 Estimates is 10,000£ for armor.

In Vote 9, the following sums are included:—70,000£ as an Admiralty payment to the War Office for Research directed by the Ordnance Committee; 4670£ for the Torpedo Experiment Station; 3567£ for the Naval Ordnance Research Department; 2696£ for the Experimental Station of Shoeburyness; 12,000£ for experiments with guns, 24,000£ with projectiles and ammunition, and 25,000£ with torpedoes, mines, etc.; a total of about 142,000£. In 1914, the Estimates contained only one corresponding amount, viz., 9800£, as the Admiralty contribution to the War Office for research work.

Vote 10 of the Estimates is for works and buildings, and amongst the sums included are 3500£ for extension of accommodation at the anti-sub-

marine establishment at Portland; 38,000£ for a high-speed experiment tank at Haslar; 2250£ for an extension of the Research Laboratory at Teddington; and 3170£ for the Research Department at Woolwich; a total of about 47,000£. There are no similar items in the Estimates for 1914.

It is probable there are other amounts in the 1928 Estimates for research and Experiment which are not so definitely expressed, but those which have been enumerated total 625,000£ and necessitate the employment of over 1000 persons in the various establishments which have been mentioned. The provision in the 1914 Estimates for the same purpose was about 20,000£. The increase is an appreciable one, and is generally overlooked by those who compare the post-war estimates with those of pre-war years. The cost for 1928 is slightly more than one per cent of the total Estimates, but nearly 7 per cent of the sum allocated to new construction, and is nearly sufficient to meet the cost of two destroyers or submarines. The value of scientific research and experiment is difficult to assess, but this can be safely left to those who have the responsibility of preparing the Navy Estimates.—"Engineering," June 8, 1928.

WELDING CRANKSHAFTS.

An interesting account is given in a recent contribution to the Proceedings of the Diesel Engine Users' Association of the welding of the cracked web of a Diesel engine crankshaft. The engine is of the type frequently used on board ship for driving the electrical generators, having three cylinders, each 340 millimeters bore (13.4 inches) with a piston stroke of 430 millimeters (16.9 inches), and developing 200 B.H.P. at a speed of 300 R.P.M. One of the webs of No. 2 crank was found to be cracked at the junction of the web to the shaft, and in a downward direction towards the shaft center, there remaining only ¼ inch of solid metal. To lift the crankshaft out of its bearings would have been fatal as it would have parted, so it was decided to weld the web in position. Nos. 1 and 2 lines were dismantled, but No. 3 was left intact and No. 2 crank pin was bound round with asbestos rope for protection. The bearing cap adjacent to the cracked web was removed to facilitate operations, but in order to retain alignment, the other bearing caps were pulled down tight on the shaft. A portable oxy-acetylene plant was utilized to "V" out the crack on one side, and after having been chipped out, the bottom of the "V" was electrically welded with vanadium steel to a height of about 1¾ inches, the breadth of the web being 12⅝ inches and the thickness 5 inches. A "V" was then cut on the other side of the web, and this was next electrically welded to the same extent as the other side. The electric welding was then continued by alternately welding each side in layers of about ½ inch until the two "V's" were filled up. The faces were then chipped and filed up flush and a plate 1⅛ inches thick secured to each side by set screws and welding round the edges. On completion the shaft was tested for alignment and found to be perfectly accurate, and it has since been in regular service.—"Shipbuilding and Shipping Record."

A NEW WHITE STAR LINER.

It was announced in Belfast on Monday last that Harland and Wolff, Ltd., have received an order from the White Star Line to proceed with the construction of "the world's largest liner," the building of which has been spoken of at intervals during the past two years. The keel of the new

vessel has been laid down in the firm's East Yard at Belfast. No official statement has yet been made regarding the actual dimensions of the new ship. It is, however, understood that she will be larger than the *Majestic* and that she will probably have a gross tonnage of 60,000, a length of 1000 feet and a beam of 100 feet. If these figures should prove to be correct, the new vessel will exceed the *Majestic*—the largest vessel in the world at the present—by about 85 feet in length and about 3350 gross tons, the beams being the same. It is estimated that the ship will cost about £7,000,000, and will take 3½ years to build. There are grounds for believing that she will be propelled by internal combustion engines, but on this point nothing definite has so far been announced. In this connection, it may be noted that all the vessels now under construction at Queen's Island, aggregating over 140,000 tons of shipping and including a 26,000-ton White Star liner, a 20,000-ton Union-Castle liner, and four 15,000-ton Nelson liners, are to be driven by internal combustion engines.—"The Engineer," June 22, 1928, p. 675.

BOOK REVIEW.

"DIE KOMPRESSORLOSE DIESELMASCHINE," BY LUDWIG HAUSFELDER; PUBLISHED BY M. KRAYN, Verlagsbuchhandlung, Berlin, W10, Genthiner Str. 39; price 20 marks, unbound; 22 marks, bound; 383 pages, 256 illustrations.

The Diesel engine reached its perfection using high pressure air for fuel injection, and only comparatively recently, especially in Germany, have concerted efforts been made to develop a reliable compressorless oil engine. A review of the large variety of means proposed by the inventors of the world to simplify the oil engine by the omission of the high pressure injection air compressor was therefore deemed by the author to be timely. For this purpose he used mostly the patent specifications, leaving it to the reader's knowledge of the oil engines now being built to pass judgment on the practicability of the various claims that were made by the inventors.

Patent specifications are important indications of the technical development in two respects: first, because they serve to disclose the inventor's conception of the means to accomplish what he sets out to do, and second, because they also indicate the inventor's aims and thereby stimulate further activity in perfecting equivalent apparatus by others.

Hence to all those that have had experience with oil engines, either in designing or operation, and wish to express their personality in the perfection of this important means of power generation, this book will offer many stimulating ideas. To the practical manufacturer of oil engines it is a handy reference book on the status of the art to date.

REVIEWED BY E. C. MAGDEBURGER.

ASSOCIATION NOTES.

RESIGNATION OF SECRETARY-TREASURER.

Due to detachment from duty in Washington, Commander H. B. Hird, U. S. Navy, resigned as Secretary-Treasurer of the Society, effective July 31, 1928.

Captain O. L. Cox, U. S. Navy, has been appointed by the Council to fill the unexpired term of Commander Hird.

CHANGE IN COUNCIL MEMBERSHIP.

The appointment of Captain O. L. Cox, U. S. Navy, as Secretary-Treasurer caused a vacancy in the Council, of which he was a member. To fill this vacancy, the Council has appointed Commander H. T. Smith, U. S. Navy.

MEMBERSHIP.

The following have joined the Society since the publication of the last previous JOURNAL:

NAVAL.

Flanders, Warren B., Lieutenant Commander, N. R., 6043 Ellsworth St., Philadelphia, Pa.

Lahn, Jackson N., Ensign, U. S. Navy.

Pratt, Charles R., Lieutenant, U. S. Navy.

Rogers, Willis N., Lieutenant, U. S. Navy.

CIVIL.

Lincoln, Joseph B., Engineering Experiment Station, Annapolis, Md.

Pope, Joseph, Stone & Webster, Inc., 49 Federal St., Boston, Mass.

Spaulding, A. B., 1001 Liberty Trust Building, Philadelphia, Pa.

Walton, Julian N., 1167 President St., Brooklyn, N. Y.

ASSOCIATE.

Bittencourt, Raul Regis., Lieutenant Brazilian Navy.

Lapham, Edward A., General Manager, Morganite Brush Co., 3302 Anable Avenue, Long Island City, N. Y.

Mar, Pellian T., The Kiangnan Dock & Engineering Works, Shanghai, China.

Setzer, B. W., 3100 Connecticut Ave. N. W., Washington, D. C.

Treat, Burnett F., Engineering Experiment Station, Annapolis, Md.